economics as if people and the planet mattered

No Catch Investment

Investing to restore European fish stocks

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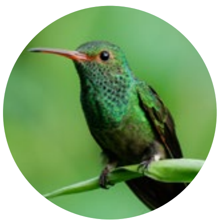

Natural Economies

Social Policy

Valuing What Matters

Well-being

nef (the new economics foundation) is a registered charity founded in 1986 by the leaders of The Other Economic Summit (TOES), which forced issues such as international debt onto the agenda of the G8 summit meetings. It has taken a lead in helping establish new coalitions and organisations such as the Jubilee 2000 debt campaign; the Ethical Trading Initiative; the UK Social Investment Forum; and new ways to measure social and economic well-being.

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Executive Summary

Overfishing in Europe is a huge economic and environmental problem. It is also eminently solvable – by fishing less for a short period of time we can rebuild fish stocks permanently. Our research quantifies the short-term costs of restoring fish stocks and finds they are easily affordable.

Fish stocks are an essential public resource facing potentially irreversible damage. Years of overexploitation have left nearly half of all North East Atlantic stocks over-fished, significantly worse than the global average. Tens of thousands of jobs and millions of tonnes of food supplies have already been lost to overfishing, with more at risk if the damage caused by over-fishing becomes terminal – already, the fishing industry has become dependent on subsidies to survive.

Halting overfishing would allow fish stocks to recover. But this would need to overcome short-term costs to fishing revenues and unemployment. In this paper, we assess these short-term costs against the potential benefits of a restored and sustainable fishing industry. We find the short-term costs, while concentrated in the fishing industry, can be overcome affordably with a relatively small investment. Moreover, the investment will pay compensation for the entire foregone income of all fishermen affected, meaning there will be no unemployment. In sum, restoring fish stocks offers enormous positive net economic returns to European Union (EU) citizens.

We argue that the costs resulting from temporary cessation of fisheries should come from private funds; with public funding targeted towards creating a favourable context for this investment to happen. This will require eliminating subsidies that contribute to overfishing; and using them to restore and maintain fish stocks at their optimal level.

Policy has focused for too long on the short-term costs to the fishing industry of transitioning to healthy fish stocks, at the expense of accounting properly for the benefits to both the industry and public. Our research shows that the benefits far outweigh the costs of a pause in fishing.

Of 54 North East Atlantic fish stocks studied here (out of more than 150 in European waters), 49 are overfished. For these 49 stocks we look at the costs against the benefits of halting fishing until fish stocks have recovered, paying compensation to the industry. We find that:

Restoring these stocks could deliver up to £14.62 billion per year in gross revenues. This is 2.7 times the current (2010) value of their landings

The size of investment required to achieve this is £10.4 billion over the entire transition period (9.4 years) – £9.16 billion in present value terms

The profit[1] of such an investment over the transition period alone is a positive £4.43 billion – calculated as the additional benefits over and above current catches, and with investment subtracted. Over a 40-year period (2013-2052) the profit is £120.2 billion, with a transition scenario delivering twice the value of catches as without a transition (£260 billion compared with £130 billion)

The returns on investment are 148 per cent over the transition period – calculated as the additional value divided by the investment. For every Euro invested, £1.48 is returned within this first decade. Within the first 40 years (2013-2052), the returns are £14 for every £1 invested. Given that all stocks are restored to their full potential (MSY) by mid-2022 – and most within five years – the benefits continue to be generated indefinitely as long as fishing does not exceed MSY

These results assume that the entire existing fishing fleet exploiting these fish stocks will be adequately compensated over the transition period. This is not to say that the current fleet size is optimal. Many have argued that, given current fish resources, the fleet is currently two or more times its appropriate size. We keep the debate about ideal fleet capacity separate from the economic argument for rebuilding fish resources, and so we assume the fleet stays the same size throughout.

Adapting this to practical policy would require the consideration of more social and economic factors than we have studied here: socially optimal rebuilding trajectories and fishing effort reductions, fleet restructuring to increase the gains for society for each tonne of fish caught, exploring alternative employment options for those in the industry, as well as nutritional impacts for consumers, and other issues for wider society.

Despite the environmental and economic costs of overfishing there has been little public debate about restoring fish stocks and making the amount of investment available. With the reform of the Common Fisheries Policy and its financial mechanism in motion, but few promises for a real change in the status quo, the prospect of another decade of overfishing looms ahead. We show that restoring stocks is affordable, profitable, and necessary.

Atlantic Mackerel by Toni Llobet

Introduction

"Any tendency to overfishing will meet with its natural check in the diminution of the supply… this check will always come into operation long before anything like permanent exhaustion has occurred"

Thomas Huxley

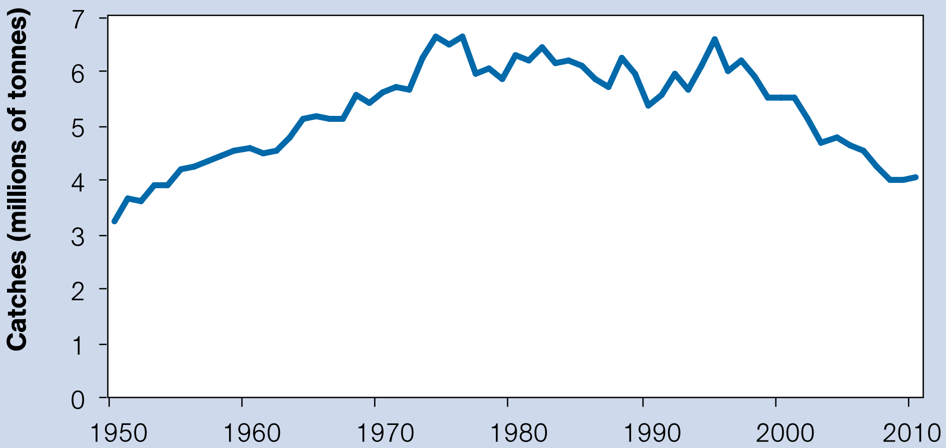
The decline of fish stocks

Fish are an incredibly valuable public resource. If managed properly, they are also a fully renewable resource; as long as we leave enough fish in the sea to reproduce there will be more for us to catch in future.

Unfortunately, decades of mismanagement have left European fisheries in a dire state. Overfishing now occurs in all of Europe's major fishing grounds. An average of 79 per cent of assessed stocks in the North East Atlantic were considered overfished during the period 2005-2012, and 47 per cent in 2012.[2] This compares with the global average of 29.9 per cent[3] (see Figure 1). Overfishing reduces – sometimes drastically – the productivity of fish stocks and even the capacity of the Oceans to sustain their historical levels.[4] Catches of North Sea cod alone are less than one fifth of what they could potentially produce if fished sustainably.[5,6]

Overfishing is a failure of management. European Union (EU) fishing quotas (the catch limit in a given year) have been consistently set at unsustainable levels. Total allowable catches in the Northeast Atlantic stocks were set an average 41 per cent higher than the sustainable level between 2003 and 2012.[7] From 1987–2011 quotas were set above scientific recommendations in 68 per cent of decisions for 44 stocks in EU waters.[8] The effect of this political failure is fewer fish to catch and lost revenues, which has led to us subsidising the fishing industry by hundreds of millions of Euros each year.[9] These are not the only cases of mismanagement: discarding,[10] habitat destruction,[11,12,13,14] lack of scientific knowledge,[15] poor policy transparency and non-compliance[16,17] have all damaged European oceans over the past few decades.

Figure 1: EU catches in the North East Atlantic and Mediterranean, the EU's main fishing grounds. Here, the EU is the EU27 or an aggregation of its current member states.



Source: Eurostat Statistics.[18]

The economic drain of overfishing

Overfishing has huge economic as well as environmental costs. European fish stocks are smaller than they could be and less resilient so they generate lower revenues and profits as well as fewer jobs. Globally US$50 billion of revenue is lost every year due to overexploitation of fish stocks.[19] Likewise, overexploitation of 43 (out of more than 150) North East Atlantic stocks results in a loss €3.2 overall (€1.8 billion annually to the EU).[20] At present, not only are we bearing the costs of past overfishing, we are inflicting the same costs on ourselves in the future. Sustainable fishing is necessary for the economic viability of fishing fleets. This was illustrated vividly in Canada when the collapse of the Great Banks cod stock led to the loss of 35,000 jobs.[21] While not as dramatic, the trend in the UK is strikingly similar (Figure 2).

The economic benefits of rebuilding fish stocks

Managed and fished properly, European waters could provide more food, more money and more jobs into our economies. This requires us to rebuild fish stocks – fishing less in the present (allowing fish to grow in size and number) so that we can fish more in the future. Unlike man-made capital, fish populations require no investment other than our patience. As the populations recover, so does their economic value.[24]

The fishing industry requires a continuous throughput of fish for its survival and to pay the interest on its capital investment. Diminishing catches due to overfishing are leading to falling employment in the industry.

In the **nef** report *Jobs Lost at Sea*[25] we estimated the economic value of fishing 43 North East Atlantic fish stocks at their maximum sustainable yield (MSY), compared with the value currently derived from their overfished states. These calculations are re-done in Figure 3 to include another 11 stocks (to a total of 54) in the region (see technical appendix for differences in methodology used).

MSY numbers are estimates. If the MSY is higher than estimated the benefits of rebuilding fish stocks would be even higher than projected. However, given the scale of the benefits of rebuilding, even the lower confidence limits for MSY estimates are likely to lead to overwhelmingly positive investment returns.

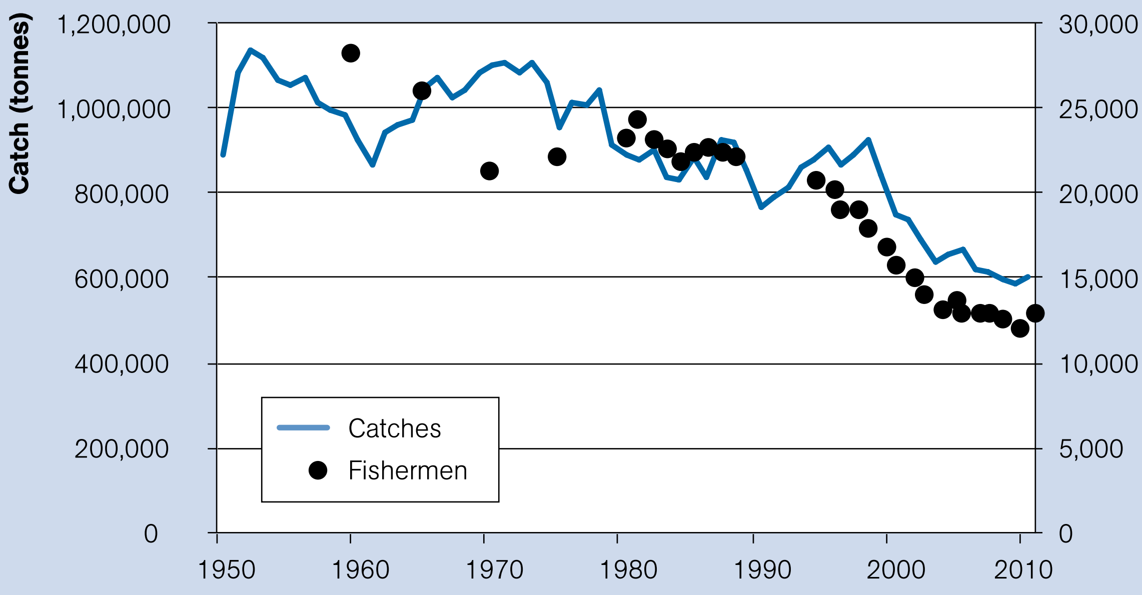
Sustainable Fishing

The maximum sustainable yield (MSY) is the largest annual catch that can be sustained by a fish stock indefinitely. It is possible to fish sustainably but far below the stock's MSY.

Overfishing is commonly defined as occurring when fish catches (or, fishing mortality) exceeds the biological replenishment rate of the stock (i.e. we are catching fish faster than they can replace themselves). When this happens for long enough the stock size diminishes, and in general so too does its replenishment rate.

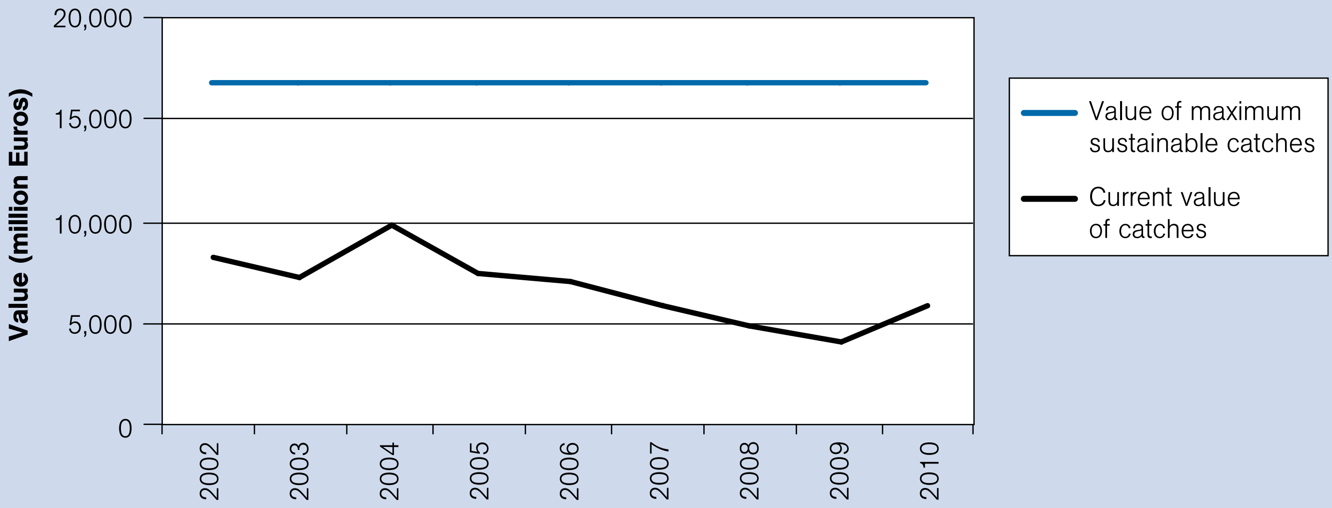
We apply the definition of overfishing relative to MSY. If the fishing mortality (roughly, how many fish are caught as a fraction of the population) is higher than the mortality that would support MSY, the stock is being actively overfished since it will never reach its full potential (if the current biomass is less than that supporting MSY fishing). If this type of fishing continues for long enough, the stock size (its biomass) will diminish. Also, if the stock's spawning biomass is smaller than that which supports MSY (i.e. BMSY), the stock is in an overfished state. To avoid overfishing a stock there is a strong case for MSY to be used by management to be used as a limit rather than a target.

Figure 2: Overfishing has led to smaller, less productive fish populations which in turn support smaller and smaller catches. Smaller catches reduce fishing revenues and undermine the financial viability of the fishing industry, leading to increasing unemployment. The correlation between catches and the number of fishermen is 0.864. Data are UK catches (landings) from all fishing areas, and fishermen in the UK.



Source: Catches from Eurostat Statistics,[22] fishermen numbers from the UK Marine Management Organisation.[23]

Figure 3: The current value of catches from 54 fish stocks are shown relative to their sustainable maximum. MSY values are in 2011 prices, while current values are nominal. Source: MSY estimates from Froese & Proelß[26] and current value of catches are own calculations based on ICES stock assessments and the AER.[27] See technical appendix for methods.



Short-term costs of rebuilding fisheries

The costs of collapsed fisheries can be devastating.[28,29] Successfully rebuilding fisheries merely requires a reduction in fish catches so that fish reproduction can increase. However, fear of the short-term costs of rebuilding stocks has prevented policymakers from acting to restore our fisheries. This report takes a new approach, calculating the short-term costs of rebuilding fish stocks and treating it as an investment decision.

In the main the short-term costs of rebuilding fish stocks will accrue to the fishing industry. So, we calculate the size of investment fund that would be needed to mitigate short-term costs for fishermen and ensure the delivery of the benefits once the fisheries are rebuilt.

Our numbers are based on a rapid transition for the industry: the minimum time required to achieve the maximum catches possible. In other words, we calculate how long it would take to rebuild a fish stock if we stopped fishing it altogether.[30]

We assume the investment required must be sufficient to cover crew (labour) and depreciation costs for the duration of moratoria on all overexploited fish stocks. For simplicity we assume there are no knock-on effects (e.g. impacts on the value chain[31]) which cannot be compensated by increases in net imports or shifting fishing pressure onto other fish stocks. In reality, to avoid overfishing these other fish stocks, consumers would likely need to temporarily reduce consumption until each fish stock is rebuilt, after which their consumption could significantly increase.

Restoring fish stocks has a number of socio-economic costs, but no environmental costs. On the other hand the environmental costs of overfishing are significant – if environmental changes are too severe then the recovery potential of fish is limited, and may result in ecosystem regime shifts, as have been observed in at least Canada,[32] the North Sea,[33] and the Baltic Sea.[34]

Social costs encompass the disamenity of a temporary fall in fish supply, and a disruption to coastal communities. Economic impacts include a temporary fall in revenues and employment. Most of these costs are borne by the fishing industry, just as it has accrued many of the short-term benefits from overfishing. It is clear that all costs can be more than paid back by restored stocks fished indeterminately at their maximum sustainable level.[35] The social impacts of transitioning to healthy fish stocks are more fully discussed elsewhere.[36]

Who will fund the transition?

The rates of return shown in results (e.g. Table 1) show that investing in rebuilding fish stocks could be enormously profitable. We envisage such rates to attract private capital. Such private investors would also determine some of the conditions of investment. One condition would likely be that the fleet be reduced to a sustainable size[37] to ensure that rebuilt stocks are not overfished again, undermining the asset's value.

Such conditions demonstrate the potential use of public funds: to create the appropriate context for private funding of the investment. Public funds should not be used to aid temporary cessations in fishing. Doing so would risk creating perverse economic incentives that reward overfishing by covering all associated costs of fishery failure, as well as directing the little public funds that are available away from other measures which can support stock recovery. Public funds should in particular be used for control and enforcement (particularly during a transition of no fishing) and data collection. Another positive measure is to support biodiversity via support of Natura 2000 sites. While there are valid concerns about de-commissioning schemes,[38] public funding can also contribute to implement fleet capacity reductions according to social and environmental criteria to ensure the restructured fleet delivers positive net value to society.[39]

Whilst the transition investment is well-suited for private capital, with some part of the returns being generated as profit for private investors, the public could also benefit through the taxation of natural resource use. In addition, the public would benefit from the enormous increase in fish supply, here estimated to overtake current supply within just 4 years.

Recent research has demonstrated the economic benefits of rebuilding fisheries on a global scale.[40] The benefits of rebuilt fisheries are estimated at 89 million tonnes per year in catches, worth US$101 billion per year. In this scenario, the costs of fishing are reduced markedly (from the current US$73 billion per year to US$37 billion per year) because of the abundance of fish, making them easier (and cheaper) to catch, as well as a reduction in fishing capacity (boats and fishers) to a level that maximises economic profits with catches at MSY. The economic profits ('rents') from rebuilt fisheries are estimated at US$54 billion per year, close to the US$50 billion per year estimated by the World Bank and UN.[41]

Overcoming these short-term costs is a challenge yet, when put in perspective with the potential benefits, eminently affordable. It is also worth considering the alternative: the status quo, where continued overfishing undermines food security, employment, and economic revenues.

Fleet size and capacity

This paper attempts to be neutral about the appropriate capacity of fishing fleets in order to distinguish the arguments of fleet capacity from the economic case for rebuilding fish stocks. As such, we assume the fleet is maintained at its current size, and there are no government 'buy backs' of overcapacity vessels – nor purchasing of new vessels – throughout or after the transition period.

The use of compensation to the existing fleet as a way to estimate transition costs is not an argument for the fleet to remain at its current size. Indeed, there is evidence that the fleet is too large for the current fish resources and should be reduced.[42,43] This could be done in a selective way that prioritises those segments of the fleet that deliver the greatest positive value to society, while eliminating the most harmful.[44] How fleets are restructured and which objectives are prioritised (e.g. investment in capital and employment) also could determine who benefits from the public resource once rebuilt.

We have not explored how the investment in the fishing industry should be distributed or what should be done with the human and physical capital not deployed catching fish. We do not recommend that fishermen be paid compensation to do nothing, indeed there are a number of alternative activities they could take part in while stocks are being rebuilt such as data collection, monitoring and enforcement, collecting waste, and so forth. It is beyond the scope of this research to examine these.

Reducing fishing effort during the moratoria

In general our research assumes that fishing effort is, and can continue to be, adequately controlled with current monitoring and enforcement. This section outlines further considerations if we were to introduce moratoria on fishing certain stocks.

Reducing catches in the short-term requires a reduction in fishing effort. Conventional understanding of the level of fishing effort is based on the economic profitability of entering into, or exiting from, a fishery and each fishing operation of the season. Such profitability depends on private fishing costs, landing values, stock abundance and fish catchability, and other factors, such as government subsidies. There are also many other non-profit factors determining fishing effort and the willingness of fishers to exit a fishery,[45] including cognitive, cultural, and socio-economic factors,[46] occupational attachment and identity,[47,48,49] age, education and ethnicity,[50,51,52] expectations of large economic gains,[53] and availability of alternative employment.[54] These factors, and their relative importance in a site-specific context, are important to understand when seeking to rebuild fish stocks based on a voluntary approach.

Controlling fishing effort during a transitory period of rebuilding stocks can influence many of these factors directly or indirectly. There are two main approaches to controlling fishing effort: voluntary and market-based mechanisms, and the monitoring and enforcement approach. In the former, the role of non-financial factors (e.g. cultural) may prevent economically rational decisions being made. This means that, where overfishing has reduced catch

Reforming the EU fleet for sustainable fishing

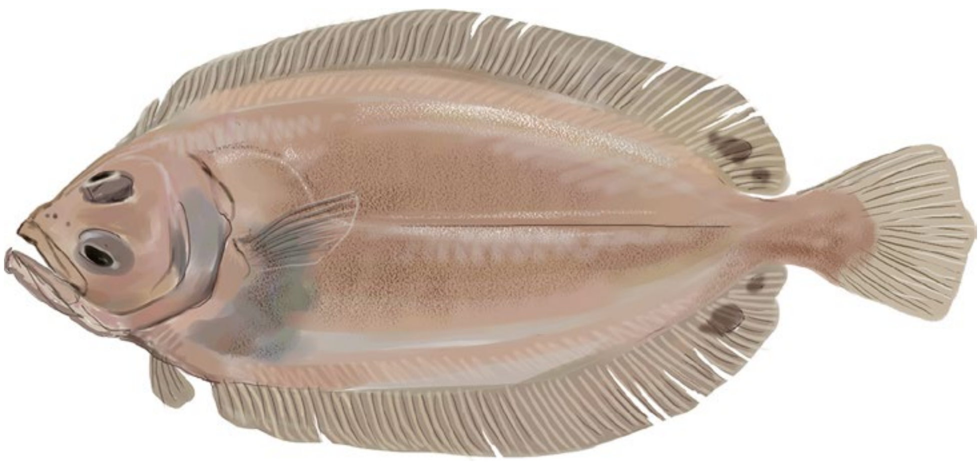
The EU fishing fleet has been estimated, in some fisheries, to be two to three times larger than its sustainable size.[55] Reducing the fleet is a crucial aspect of building sustainable fisheries; even with a temporary cessation in fishing to allow stocks to rebuild to their optimal sizes, without fleet capacity reductions the stocks are likely to be depleted once again. This would undermine the value of the fish stocks, food supply, and returns on investment, and make future private investment less likely due to the risk of poor returns.

This report, however, assumes a constant fleet size in order to both simplify the message and to distinguish the debate about fleet capacity from the economic argument for rebuilding fish stocks. Proper fleet management, however, should ensure that capacity is reduced during the transition so that the fleet is an appropriate size at the end of the moratoria. Reductions in fleet capacity should keep those segments of the fleet most conducive to sustainable fishing while eliminating the most harmful. For example, gillnets fishing in the North Sea were found to generate a positive value of £865 per tonne of cod landed, while the largest trawlers destroyed societal value to the tune of -1992 per tonne of cod landed.[56]

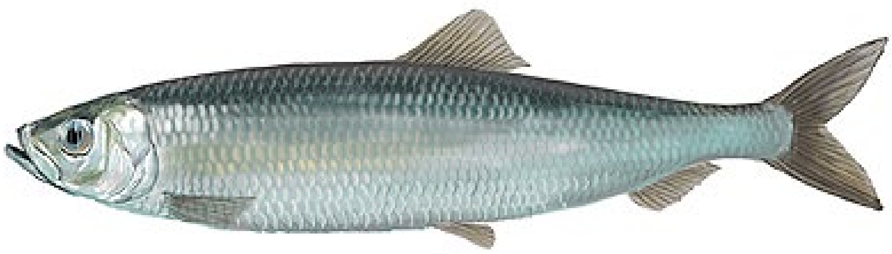
The Common Fisheries Policy must create the context – such as using access criteria – to favour those elements of the fleet that benefit society the most, while eliminating the most harmful.

revenues, fishers are less likely to leave a fishery than would otherwise be expected if profitability were the main concern. What this demonstrates is a partial disconnect between changing environmental and resource conditions and the fishery's willingness to adapt to these changes. As applied to this study, and where these non-financial factors are dominant, reducing fishing effort in overfished North East Atlantic stocks based on voluntary decisions may be partially or entirely inadequate to achieve stock rebuilding.

The alternative approach of controlling access based predominantly on monitoring and enforcement may have more success. In this case, fishers are forbidden by law to fish certain stocks while they are being rebuilt, enforced by penalties or encouraged by the offer of private investment. However, we can still expect voluntary decisions – such as deciding whether to flout the moratoria and risk fines if caught – to play a role. In addition, the incentive to break the moratoria will also have financial factors at play, with the fall in catches possibly leading to a rise in prices (up to the international price of that fish species in the market, above which consumers would choose to import their fish instead). This rise in prices incentivises fishers to risk the penalties or not accept the investment being offered. The penalties of ignoring the moratoria should, therefore, be sufficient to deter the behaviour, and this must outweigh the aforementioned non-financial factors, such as the disamenity of lost identity, as well as the financial ones.



Four Spot Megrim by Toni Llobet



Clupea harengus by Toni Llobet

Methodology

Restoring fish stocks requires a transitory period in which fewer catches are made. This reduction could be done gradually or rapidly. Ours assumes the fastest of all – a complete halt to fishing in the overfished stocks. This in turn leads to a dramatic fall in fishing revenues.

Summary of Methodology

A temporary cessation in fishing in turn leads to a dramatic fall in fishing revenues. This approach would not be adopted by policymakers unless the future is judged as valuable as today (which is not standard practice in economics). Instead, it shows the possibility and affordability of restoring fish stocks in the shortest time horizon. A more realistic scenario that gradually reduced fishing would lengthen the recovery time and make the investment required more affordable, but it would also, unfortunately, lead to further unrealised benefits and, in turn, delay the full benefits. This report suggests that, given the potential return on investment, the net benefits would be largest for the shortest recovery time.

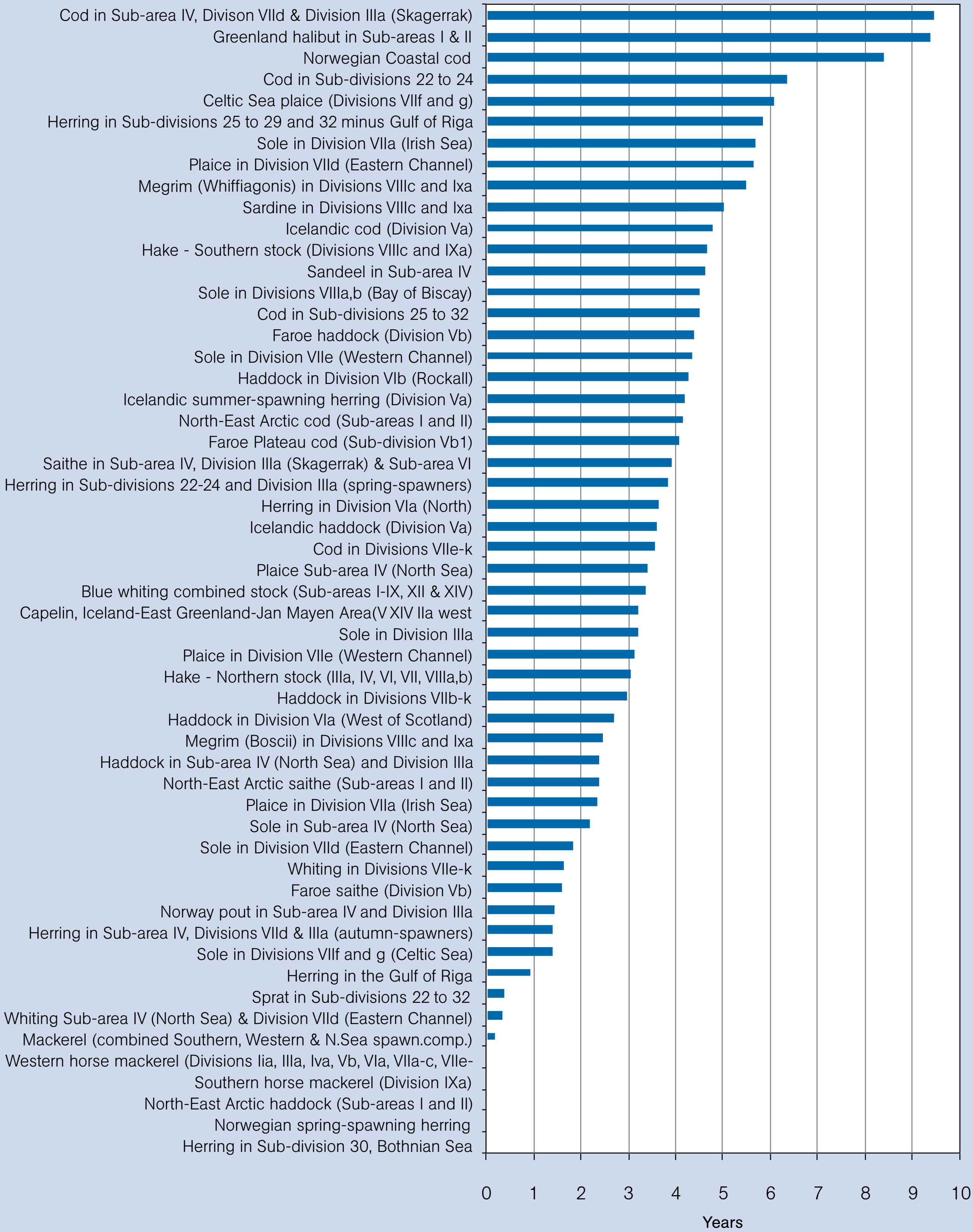
Without fishing, stocks begin rebuilding immediately, and most fish stocks can be restored within five years. Moratoria are placed on all overfished stocks (49 out of 54) for the duration of the rebuilding phase, and as each reaches its potential, fishing can resume. Since some stocks have a recovery time of less than one year, fishing resumes almost immediately for a number of stocks. Most of the restoration value has been achieved within four to five years, with another four years only being imposed on a very few exceedingly overfished stocks (e.g. North Sea cod). The time taken for these stocks to be restored is shown in Figure 4. The size of current catches compared to their maximum is also shown (Figure 3 and Technical Appendix Table A4 and Figure A4).

In normal times a fall in fishing revenues would lead to a fall in employment. We argue, however, that sustaining employment during the decline in revenues should be a priority, and as such it makes up the largest share of the transition investment. Our model ensures that all crew income that would be generated from status quo fishing would continue as is.[57] The same applies to depreciation costs, which are covered to ensure that the fleet can return to fishing once the moratorium ends. These two costs – crew and depreciation of vessels – require an investment. It is an investment because it retains the skills and means to exploit the fish stocks once they are rebuilt, and generates a return on the initial financial commitment.

Calculating the investment required to cover the shortfall in revenues during the moratoria requires deriving the aggregate crew and depreciation costs across all fleets fishing all fish (in EU waters and further afield). Next, these are scaled to a level corresponding to each stock's contribution to those costs according to their catch values. For example, if one stock makes up half of a fleet's catch value, then it also pays for half of its crew costs. In addition to these two costs, we also estimate the size of the short-term reduction in catches (weight and value) based on the average of recent catches.

We compare these investments with the potential value of fish stocks fished at their MSY. This value was estimated by multiplying MSY estimates by the value of the stock per tonne. All figures are in 2011 Euro real prices, and future values are discounted unless otherwise stated. While fishing at MSY would lead to far higher catches for most stocks than current catches, we do not model the fall in price that normally occurs when supplies increase. This is because this report does not seek to model fish market dynamics, particularly when MSY would lead to increases so

Figure 4: Time taken to restore fish stocks. If fishing stopped on 1 January 2013 (= time 0) then it would take around 1 year for herring in the Gulf of Riga to recover. The rebuilding time of the 54 stocks depends on their current size (spawning stock biomass (SSB)) and their potential size (B_{MSY}), while assuming that their growth is logistic in nature. See the technical appendix for details. Of the 54 fish stocks in this study, 49 are below their B_{MSY} level, and five are above: two herring stocks (her-30 and her-noss), one haddock stock (had-arct), and two mackerel stocks (hom-soth and hom-west).



Source: ICES[58] and Froese & Proelß.[59]

large that conventional price flexibilities of 0.2 would assign a price per tonne of zero to some stocks. Instead, the aim is to demonstrate the potential value of fishing at MSY based on our current valuation of these fish.

We studied 54 fish stocks distributed throughout the North East Atlantic Ocean. Of these, 49 are currently in an overfished state, defined as having a current biomass smaller than B_{MSY} (the biomass size which supports fishing at MSY). Our first step was to calculate each stock's recovery time in the absence of fishing, which is estimated using current and potential biomass figures, and assumes logistic growth of the stocks. The investment required to cover crew and depreciation costs is then estimated for each stock based on its relative share of the total landing value obtained by fishing all stocks. The same method is used to estimate the number of fishermen affected by the moratoria. An average of recent catches is used as the status quo, alternative scenario. The potential benefits are estimated by multiplying MSY figures for each stock by species-specific prices. All values are in 2011 real prices (Euros) and discounted at 3.5 per cent annually unless otherwise stated.

See the Technical Appendix for a more formal treatment of our methods.

Costs of transition

Restoring fisheries requires a reduction in fishing for a number of years until fish stocks recover. This has a number of costs: fall in catches, fall in revenues, employment implications, impacts on the processing sector and the wider economy. Some of the costs associated with fishing continue despite the absence of fishing, such as capital costs and depreciation costs (though we expect the latter to be lower without fishing). Other costs, particularly the variable costs of fishing (e.g. fuel use), are zero when fishing is stopped.

The full list of the economic factors related to fishing is shown below, along with their treatment in this study:

- Crew costs: Covered by the investment fund to ensure zero unemployment

- Depreciation costs: Covered by the investment fund to ensure the fleet can functionally return to fishing post-moratoria

- Fixed costs: Not covered. Can be considered as one-off payments (e.g. the purchase of a fishing vessel) made in the past and which are independent of fishing level

- Capital costs: This is composed of depreciation costs and the opportunity cost of capital. The depreciation costs are covered, while the opportunity cost is not considered a direct expense and therefore not covered (although it is estimated in Table A2)

- Interest on the capital: The opportunity cost is not considered a real expense and therefore not covered in the main results, though it is estimated separately. Capital could be used for non-fishing activities and therefore diminish the investment required. In practice, it is difficult to convert fishing capital to other uses[60]

- Direct subsidies: Not covered

- Other income: Not covered. Not fishing-related

- Landing and total income: Not covered

- Profit and losses: Not covered due to the moral hazard of doing so. Past profits were, at least in part, derived from overfishing and should not be compensated for when stocks must be rebuilt

- The following are all considered zero in the absence of fishing and, therefore, not covered: variable costs, repair costs, energy costs (fuel use), unpaid labour, rights-based income and costs.

Given this, the investment required to fund the transition to healthy, rebuilt fish stocks should cover the costs that continue in the absence of fishing and which must be covered for fishing to resume: crew and depreciation costs. Covering crew costs means that there are no consequent employment impacts due to the moratoria: fishermen earn exactly the same regardless. This preserves the skills and experience of fishermen in the industry, as well as affording coastal communities, families and themselves no financial difficulties. Their vessels will also depreciate over time (though possibly less when not in use). Covering these costs with the investment means that vessels on 'standby' during the moratoria can resume fishing afterwards.

In both cases we overestimate the investment required: covering crew costs implies that fishermen have zero opportunity cost for their labour. In other words, they have no other possible employment options. In reality, many could successfully find alternative employment while stocks recover, and so diminish the necessary size of the investment. Regarding depreciation, we assume these to bze the same in the absence of fishing, yet they are likely to be smaller.

Since catches must fall for stocks to be restored, there is also a short-term cost in lost catches. This is not covered by the investment, but is an additional cost that must be borne by consumers in order to secure higher sustainable consumption in the future. Ideally the investment would cover these knock-on impacts, such as lower nutrition (should other fish stocks be unable to substitute for the lower catches), but this was judged beyond the scope of this study.

The revenues from these foregone catches are not part of the investment fund either. The revenues serve to cover the costs of fishing (including crew costs), and provide profits. Given that the costs are being covered, the only other component of revenues is profits. These are not covered by the investment fund because of moral hazard: the profits that have been made from fishing are, at least in part, derived from overfishing. On the other hand, many fishing operations are unprofitable, making losses instead of profits. The investment fund is designed to cover the costs of not fishing, so there should be no losses during the moratoria period (even if there are losses under the status quo).

There are also other costs which might come into play, such as an increase (or fall) in monitoring and enforcement costs. These are not considered in this paper but could be modelled in future work. As this treatment demonstrates, the purpose of this paper is not to be an exhaustive cost-benefit analysis of alternative policies, but to capture the main elements of a transition policy. This serves to refocus the urgency on restoring stocks for the sake of future benefits, while estimating the size and affordability of the present investment required for the transition. Whether this is done as rapidly as we model, or over a longer period, is for others to decide.

Benefits of transition

There are a number of positive factors at play from restoring fish stocks. In the short-term, these include a reduction in fuel use (and greenhouse gas emissions), improvements in the ecosystem, and the rebuilding of the fish stocks themselves. While we assume that there are no alternative productive uses of either fishermen or their capital (e.g. boats), there are likely to be significant uses for them in the economy (which should diminish the investment needed). While there may be others too, the only one we consider is the value of restoring stocks. These are estimated as the value of fishing each stock at its MSY once their stock size has reached B_{MSY}.

Results

The results demonstrate a significant investment opportunity in restoring fish stocks.

Main results

- The size of investment required to restore the overfished stocks is €10.56 billion over 9.4 years (2013–2022) (discounted to present value terms)
- The entire investment is recovered within 4.6 years. Fish supply surpasses current levels within 4 years
- The gross benefits of a transition are €69.41 billion over 9.4 years (2013-2022), and €299 billion over 40 years (2013-2052) (discounted to present value terms)
- No transition means catches continue at an undiscounted value of €7.04 billion per year, a loss of €9.81 billion per year
- In present value terms, the gross benefits would be €15.66 billion over 9.4 years, plus €16.85 billion for every subsequent year, for an investment cost of €10.56 billion. This is a net gain of €5.104 billion during the transition alone
- In NPV terms, over a 40-year period (2013–2052), the value of the transition is €138.56 billion.

The headline results are shown in Table 1 (and Table A6). These figures make a compelling case for restoring stocks as quickly as possible, particularly in the current economic crisis.

The results are surprising; to put them into context it is helpful to bear in mind the typical (equity) returns on investment found in the UK, EU and around the World (Table 2). For the World, the ten-year average return has been just 1.2 per cent.

Table 1: Main results of the study, showing the investment and benefits from transitioning to healthy fish stocks in aggregate form (over 2013 to mid-2022) and on a per EU27 citizen basis. All figures are calculated over the duration of the transition period only, while the benefits would, in fact, continue indefinitely into the future. It should also be noted that the values per EU27 citizen assume that EU27 citizens designed to make the figures more tractable, and do not suggest they subsidise the fleet for the transition; they are also inflated by excluding citizens from non-EU27 countries. This, therefore, should be seen as the maximum any citizen would need to pay (e.g. through pension investments), and likely much lower for EU27 citizens.. The total, non-discounted value of catches from restored stocks is €16.851 billion every year, which should be added to the value of catches for all years after 2013, after discounting.

Figures summed over 2013 to mid 2022	*Total*	*Per EU27 citizen*
Transition Investment Required (mEUR)	10556	21
Value of catches from rebuilding stocks (mEUR)	69410	138.3
Business as usual value of catches (mEUR)	53750	107.1
Subsidies (mEUR)	5258	10.5
Net present value (mEUR)	5104	10.2
Return on investment	148%	148%
Return on investment	149%	149%

Source: Own calculations.

Table 2: Return on investment figures for year-to-date (YTD), 1-,3-,5-, and 10-year timeframes. Data are annualised growth averages in Standard Cap (Large+Mid Cap) equity.

Country/Regional Performance	*YTD*	*1 Yr*	*3 Yr*	*5 Yr*	*10 Yr*
UK	3.48	4.64	11.60	-5.10	-0.42
US	12.15	22.44	19.94	2.40	1.74
Japan	3.73	2.84	4.13	-8.83	-3.54
Switzerland	3.12	-0.42	13.39	0.56	3.55
Germany	3.66	-10.63	8.61	-4.23	1.97
Greece	-7.98	-53.65	-36.39	-35.37	-14.22
Sweden	0.93	-5.80	18.03	-3.27	4.79
Europe	3.10	-1.86	9.87	-4.94	0.89
Global	7.49	10.05	14.04	-1.48	1.21

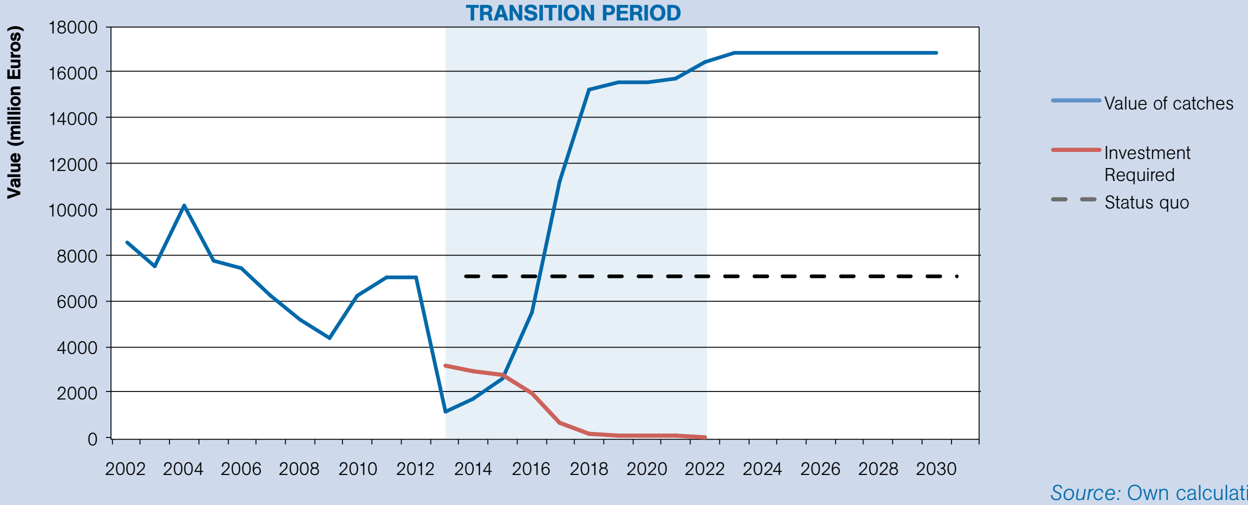
Source: MSCI.[61]

Table 3: The case for transitioning to healthy fish stocks. Under the status quo scenario, catches are assumed to continue at their current value (even if some fisheries are in current decline, and others are improving). All figures are aggregated over the time period shown. Figures are not discounted except where 'present' value is stated, and do not account for future inflation (which would, if inflation is assumed at the Bank of England target rate of 2.5% and discounting at -3.5%, lead to a net -1% compounded on future annual values). The investment is disaggregated into its components in Table A2.

Time period	*Costs and benefits*	*Status Quo: No Transition*	*Transition*	*Value of transition*
2013-mid-2022 (9.4 years)	Transition Investment Required (€billion)	0	11.965	-11.965
	Value of catches (€billion)	66.282	90.706	24.424
	Transition Investment Required (€billion)	0	0	0
	Value of catches (€billion)	215.379	515.423	300.044
2013-2052 (40 years)	Value of catches (€billion)	281.661	606.130	324.469
2013-2052 (40 years)	Present value of catches (€billion)	149.547	298.661	149.114
2013-2052 (40 years)	Present value of Investment Required (€billion)	0	10.556	-10.556
2013-2052 (40 years)	Net Present Value of transition (€billion)			138.558

Source: Own calculations.

Figure 5: Value of current and potential catches, investment required, and status quo expected catch values. All values in 2011 real prices. Catches are database sourced for 2002-2010, but an average of these values is used for 2011-2012. The investment is assumed to come into effect on 1st January 2013 and last 9.4 years to 2022. The benefits of transition continue in perpetuity (beyond the stated 2030), while the investment terminates in 2022 when all stocks have recovered. Status quo is the average value over the period 2002-2010. Values not discounted.



Source: Own calculations.

The full picture can be seen in Figure 5 and Table 3. In non-discounted terms, the investment cost is shown to start in 2013 at €3.16 billion, diminishing every year with the recovery of stock after stock (to B_{MSY}) to €28 million by halfway through 2022 (and zero thereafter).

Subsidies are also a public investment in the fishing industry, for which the return is likely to be quite low (or even negative[62]) at present. The value of catches is shown to fall to almost zero at the beginning of the investment period, in 2013. They then begin to recover rapidly, reaching their MSY level by mid-2022. The entire recovery period is 9.4 years, but as can be seen from Table 4 the catches in a transition scenario have surpassed the status quo catch level within 4 years.

The prospects for fish supply

The transition period with moratoria on all overfished stocks would require a shift in consumption onto other fish stocks, or an increased reliance on imports. However, if this shift is unsustainable, leading to overfishing in other stocks in the EU or non-EU, then consumption should temporarily fall. The period of lower consumption would be short, with rebuilt stocks delivering higher fish supply than current (2002-2010 average) levels within just 3.98 years. Thereafter, supply rapidly increases to a sustained level of 11.5 million tonnes of fish, 4 million tonnes more than current levels (Table 4). Moreover, this model is transferable: higher fish supplies could sustain consumption as other overfished stocks are rebuilt under moratoria.

Table 4: Fish supply impacts under status quo and transition scenarios. Fish supply under the transition scenario surpasses the 2002-2010 average supply within just 3.98 years of the transition commencing. Source: Own calculations based on current catches, stock recovery times and MSY estimates. See technical appendix for methods.

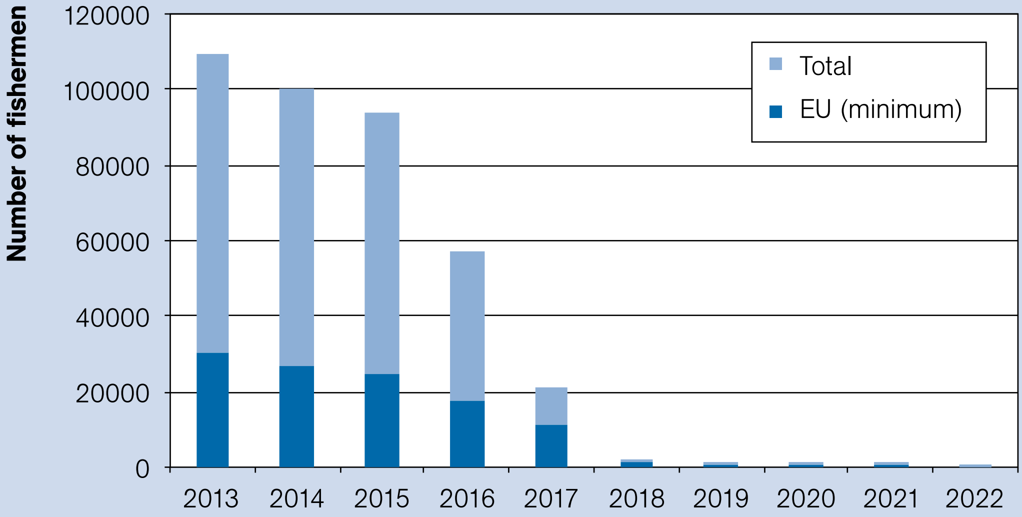
Fish supply (million tonnes)	*Year*	*Status quo: No transition*	*Transition*	*Value of Transition*
	2002	8.320	8.320	-
	2003	8.248	8.248	-
	2004	8.520	8.520	-
	2005	7.683	7.683	-
	2006	7.548	7.548	-
	2007	7.108	7.108	-
	2008	6.768	6.768	-
	2009	6.554	6.554	-
	2010	6.650	6.650	-
	2011	7.489	7.489	-
	2012	7.489	7.489	-
Transition period	2013	7.489	0.857	-6.632
	2014	7.489	1.654	-5.835
	2015	7.489	2.328	-5.161
	2016	7.489	4.442	-3.047
	2017	7.489	7.948	0.459
	2018	7.489	10.638	3.149
	2019	7.489	11.000	3.511
	2020	7.489	11.026	3.537
	2021	7.489	11.060	3.572
	mid-2022	3.093	4.580	1.486
	2022	7.489	11.321	3.832
	2023	7.489	11.485	3.997
	2024	7.489	11.485	3.997
	2025	7.489	11.485	3.997
	2026	7.489	11.485	3.997
	2027	7.489	11.485	3.997
	2028	7.489	11.485	3.997
	2029	7.489	11.485	3.997
	2030	7.489	11.485	3.997
Total	**2013-2052**	**299.551**	**416.835**	**117.284**

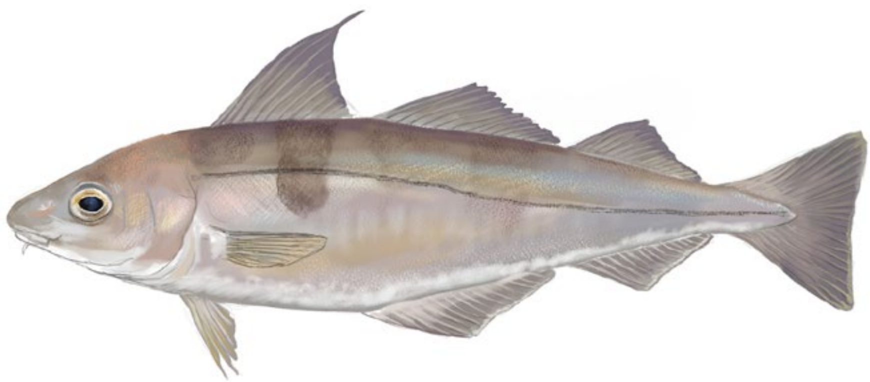
Source: Own calculations.

How will this affect employment?

The investment required covers all of the crew costs involved in fishing the 49 overfished stocks of 54 studied for the duration of their recovery. This means that there will be no unemployment caused by the transition to healthy stocks. Indeed, fishers will financially be no worse off by not fishing than fishing. Nonetheless, Figure 6 shows the number of fishermen who would need financial support during the transition.

Figure 6: The number of fishermen requiring support during the transitory period. This number declines as the number of fish stocks reaching the biomass level capable of supporting MSY increases over time. *'Total'* amounts to 109,550 jobs in 2013 across all fishing countries, including the EU, Norway, Iceland, Japan, and so on. Some of the red bar also includes EU jobs due to incomplete reporting in some of the data sources. See technical appendix for data and methods.





Melanogrammus aeglefinus by Toni Llobet

Conclusion

Long term benefits outweigh short-term costs

The economic case for restoring fish stocks is compelling. Results presented here show that fish stocks are a potentially significant, sustainable source of additional revenues into the economy, supporting thousands of new jobs.[63]

- In present value terms, restoring the 49 overfished stocks (out of 54 stocks analysed here) would require commitment to invest €10.56 billion in fishing communities over 9.4 years, with the costs fully recovered within 4.6 years and net benefits accruing thereafter

- This would lead to a drop in catches of 17.6 million tonnes during the transition period. But, within 4 years of the transition commencing, rebuilt stocks would already be providing more fish than current levels, increasing to a surplus of 4 million tonnes within 9.4 years

- The present value benefits even during these 9.4 years amount to €15.66 billion above the predicted status quo catches

- The net present value of this investment is €5.104 billion, with a return-on-investment of 148 per cent, over the transition period, and €139 billion and 1413 per cent return-on-investment over a forty-year period (2013–2052).

Real reform of the Common Fisheries Policy

The EU continues to suffer an employment crisis on an enormous scale. Better management of natural resources provides a viable and sustainable solution to some of these problems. The past few decades have helped outline the foundations of a good management structure: one that is transparent, aligned with scientific advice, adaptable, and with reliable monitoring and enforcement.

The Common Fisheries Policy (CFP) is the regulatory framework governing fisheries in the EU and its member states. It has been criticised for failing to improve the health of European fish stocks or its dependent industries. The current reform of the CFP – a once in a decade opportunity – must be ambitious enough to change fisheries into a sustainable industry independent of public subsidies and based on well-managed healthy fish stocks. Ultimately, this requires the positive gains of rebuilding fish stocks to be weighed against the short-term costs on a level playing field. To realise these benefits:

- Fish stocks must be rebuilt to the biomass that supports MSY (B_{MSY}) by 2015 – as the EU has subscribed to under the United Nations Rio+20 meeting[64] – or the earliest date possible (e.g. in fish stocks that cannot recover by 2015 even with zero fishing effort)

- A cessation in fishing, supported by private investment, is the fastest way to rebuild fish stocks and generate the greatest benefits for the public

- The fishing fleet must be restructured by prioritising access to fish resources and public money based on social and environmental criteria

- Scientific advice must be adhered to by decision makers (e.g. in setting annual total allowable catches) and decision-making must take place transparently.

The CFP must recognise the long-term gains to be made from improving the health of fisheries. As this paper shows, the short-term investment cost is vastly overwhelmed by its long-term economic benefits. The transition is affordable, economically profitable and necessary. The question is how quickly can we make it happen?

Technical Appendix

Summary of Methodology

The core concept in this paper is that to restore fish stocks then fishing pressure must be reduced. Our approach is a complete halt to fishing in overfished stocks. We estimate fish stock recovery times without fishing.

The short term costs associated with zero fishing of these stocks are simplified to labour (crew) and capital costs. Temporary falls in landing revenues are not compensated for but are considered a cost and, therefore, included in the return-on-investment calculations. Compensating labour costs ensures there the transition to healthy fish stocks would have no employment impacts though, as discussed in the report, there are alternative employment options. Capital costs are composed of capital depreciation costs and opportunity costs. The investment is designed only to cover depreciation costs, though opportunity costs are also estimated.

The investment covers these two costs for the duration of the moratoria on all overfishing stocks studied here. In mixed fisheries, where some revenue is sourced from stocks not included in this study, then the investment covers only the proportion of revenues attributable to the overfished stocks. Similarly, the number of fishers affected are calculated proportionate to the landing values of each stock.

The value of current catches from these stocks is estimated by multiplying their current landings by a price per tonne, itself estimated based on landing weight and value data from the same data source (AER). These prices are also multiplied by the MSY estimates to find the value of rebuilding stocks. All values are adjusted for inflation and discounting is also incorporated unless otherwise stated.

Consideration is also given in this section to caveats of this study and where it could be improved upon in the future.

Materials

Our data sources are listed in Table A1.

Recovery time

The time required for stocks to recover was calculated based on the current stock size relative to B_{MSY} based on the methods used by Froese & Proelß.[65] For stocks with current biomass (B_{cur}) larger than or equal to the biomass that supports fishing at MSY (B_{MSY}) the recovery time was zero. For stocks with B_{cur} smaller than B_{MSY} the recovery time (Δt) *to* B_{MSY} was estimated as:

$$\Delta t = \frac{\ln\left(\frac{2B_{msy}}{B_{cur}} - 1\right)}{2(F_{msy} - F_{cur})}$$

This assumes that increase in spawning stock biomass (SSB) follows a logistic curve. The fastest recovery for a stock with $B_{cur} < B_{MSY}$ is calculated by F_{cur} at zero (i.e. no fishing), as employed in this study. If $B_{cur} > B_{MSY}$ and F_{cur} equals Fmsy then the stock size will asymptotically approach B_{MSY} over an infinite Δt. *If* B_{cur} </> B_{MSY} and $F_{cur} < F_{MSY}$ then the stock size will approach B_{MSY} over a time period dependent on the difference between F_{cur} and F_{MSY}. Regardless of B_{cur} the stock will never reach B_{MSY} if $F_{cur} > F_{MSY}$.

This report looked at 54 fish stocks in the North Atlantic. Those for which $B_{cur} >$ B_{MSY} and, therefore, require no moratorium are two herring stocks (her-30 and her-noss), one haddock stock (had-arct), and two mackerel stocks (hom-soth and hom-west).

What is B_{MSY}?

This is the size of the stock that supports fishing at the maximum sustainable yield (MSY). Strictly, the stock size is the spawning stock biomass (SSB), rather than the total stock biomass (TSB).

Table A1: Summary of materials: Data types, uses, notes, sources and links used in this study.

Data	Use	Notes	Source	Link
MSY estimates for 54 stocks	Calculating maximum potential of the stocks (tonnes).	54 stocks, unit: tonnes, time independent	Froese, R. & Proelß, A. (2010) Rebuilding fish stocks no later than 2015: will Europe meet the deadline? Fish and Fisheries, 11(2), 194–202. Supporting information. DOI: 10.1111/j.1467-2979.2009.00349.x.	http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2009.00349.x/abstract
Recovery time for 54 stocks	Calculating recovery time for all stocks with zero fishing mortality			
Catches from the 54 stocks in 2002-2010.	Catch sizes (tonnes) used for aggregate (all countries) catches from each stock to estimate current landing values	54 stocks, unit: tonnes	International Council for the Exploration of the Sea (ICES). Multiple sources: mainly stock database except where (1) discarding is significant, or (2) data are missing. In either case landings data (excluding discards) are taken from stock summaries	http://www.ices.dk/indexfla.asp
Stock sizes of the 54 stocks in 2002-2010.	Stock sizes (tonnes) used to estimate recovery times			
Fleet catches, catch weights and revenues, fish prices, fisher (crew) numbers and their salaries, and depreciation costs for all declared fishing in 2002-2010 (N.B. this excludes many catches by these countries, though these can be found in the ICES database above)	Calibrating all variables (e.g. crew costs) as a proportion of catch weights and revenues, and applying these to catches from the 54 fish stocks. Also used to calculate the nominal price per tonne for each stock (2002-2010)	54 stocks, units: tonnes and nominal Euros (converted to real 2011 value (EUR))	Anderson, J., Guillen, J. & Virtanen, J. (2011). The 2011 Annual Economic Report on the EU Fishing Fleet (STECF-11-16). European Commission Joint Research Centre. Final EUR 25106 EN - 2011. Luxembourg: European Communities.	https://stecf.jrc.ec.europa.eu/reports/economic?p_p_id=20&p_p_lifecycle=0&p_p_state=maximized&p_p_col_id=column-2&p_p_col_count=1&_20_struts_action=%2Fdocument_library%2Fview&_20_folderId=256769
Average annualised fish-specific inflation rate (Euro)	Used to adjust all nominal 2002-2010 EUR values to 2011 real EUR values	No unit	European Central Bank (ECB)	http://www.ecb.int/stats/prices/hicp/html/index.en.html
Average annualised exchange rate (Euro to GBP)	Conversion of 2011 Euros to GBP£	Exchange rate: 1.1527	Bank of England (BoE)	http://www.bankofengland.co.uk/mfsd/iadb/Index.asp?first=yes&SectionRequired=I&HideNums=-1&ExtraInfo=true&Travel=Nix

Investment required

Two factors were used as the investment requirement: crew cost and vessel depreciation cost. The theory is that fishermen have no opportunity cost whatsoever, meaning that their skills and experience exclude them from employment in non-fishing sectors of the economy. This is a generous assumption since it is likely that, should a moratorium be implemented, at least some of the fishermen affected would find alternative employment. Instead, we assume that their entire wages must be covered by the investment so that they are financially no worse off due to the moratorium. This approach is certainly debatable: some might believe that lost profits, where they exist, should be compensated for too. However, many fishing operations actually lose money, and it is unknown to what extent the profits and losses are shared amongst the crew (and, therefore, an 'income' which might support their employment), or kept exclusively by the vessel owner. Others might take the position that the past overexploitation of public resources for personal gain should remove compensation when the resources must consequently be rebuilt. Either way, covering crew costs entirely demonstrates the scale of the challenge while being workable for those arguing for another treatment of profits/losses.

A moratorium would also have the effect of keeping ashore many vessels. Each of these will depreciate in value (perhaps due to weathering), and yet will be needed again when the stocks recover. To ensure that the fleet is not damaged by the moratorium, we also included the depreciation value of all vessels targeting the 54 stocks (scaled by landing value).

1 Crew costs

These were estimated using the following formula:

$$cr_{i,v} = \frac{CR_v \text{ x } l_{i,v} \text{ x } p_i}{LV_v} \text{, for } i = 1,\ldots,54 \text{ and } v = \textit{all member states}$$

=Where $cr_{i,v}$ is the crew cost per stock, i, per country, v. CR_v is the crew cost for all fishing trips by that country, LV_v is the landing value associated with catches from all fishing trips by that country, $l_{i,v}$ is the quantity (tonnes) landed of that stock by that country, and p_i is the price per tonne of that stock (in 2011 EUR real terms). This formula scales the crew share of landing value to the landing value of each stock by that country as a way of estimating the revenue from fishing these stocks used to cover crew costs.

The total moratorium investment required to cover crew costs for any particular stock is:

$$\sum_v cr_{i,v} = \frac{CR_v \text{ x } l_{i,v} \text{ x } p_i}{LV_v}$$

Which can also be summed over all stocks to calculate the overall crew cost.

2 Depreciation costs and opportunity costs

These were estimated using the following formula:

$$d_{i,v} = \frac{D_{v,k} \text{ x } B_v \text{ x } l_{i,v}}{L_v} \text{, for } i = 1,\ldots,54 \text{ and } v = \textit{all member states}$$

Where $d_{i,v}$ is the depreciation cost (or opportunity cost) per stock, i, per country, v. $D_{v,k}$ is the depreciation cost (or opportunity cost) for the whole of a county's fleet on a per vessel, k, basis (as opposed to a sample of the fleet on a per vessel basis). B_v is the total number of vessels in the country's fleet, L_v is the quantity of catches (tonnes) from all fishing trips by that country, and $l_{i,v}$ is the quantity (tonnes) landed of that stock by that country. This formula assumes that depreciation costs are uniform across the fleet and multiplies this cost per vessel by the number of vessels in the stock sample fleet, itself estimated based on the share of the stock's catches of total catches. As with crew costs, depreciation costs can similarly be summed over all stocks, all countries, or both.

Both crew and depreciation costs were calculated as above for each year in the period 2002-2010, and averaged, to deduce the final crew and depreciation cost per stock and country.

Table A2: Disaggregation of the investment fund (crew and depreciation costs) and opportunity cost of capital. Figures rounded.

Investment fund	Value (€m)
Crew costs	11091
Depreciation costs	874
Opportunity cost of capital	279

Source: Own calculations.

Table A3: Figures corresponding to Figure 6 on employment impacts of the transition to healthy fish stocks.

	Year									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EU (minimum)	30580	26636	24913	17690	11523	1331	441	408	408	159
Total	109550	100328	93868	57235	20813	2122	847	737	737	513
Total (over EU)	78971	73692	68955	39545	9290	791	407	329	329	354

3 Foregone catches

A third impact is that of foregone catches. Whilst not a part of the investment package, the catches themselves are of significance nutritionally and to the processing sector. The moratorium-caused reduction in catches is estimated as the average level of catches over the period 2002-2010 multiplied by the moratorium period of each stock.

Employment impacts

All crew costs are covered by the investment fund, meaning that there would be no consequent loss of jobs while the stocks recover. The number of fishermen affected is calculated by estimating the number of vessels required to fish the stocks currently, and multiplying this by the average number of fishermen per vessel (Table A3). The data is sourced from the AER.[66] The formula used is:

$$FTE_{i,v} = \frac{F_v}{N_v} \times \frac{l_{i,v}}{L_{i,v}}$$

Where $FTE_{i,v}$ is the number of fishermen (full-time equivalent) in country affected by a moratorium on stock i, F_v the number of fishermen in that country's fleet, N_v the number of vessels in that country's fleet, $l_{i,v}$ and $L_{i,v}$ the catches of the sample 54 stocks and aggregates for all stocks by that country, respectively.

Other investment factors

Other impacts could be covered by the investment. For example, fishing revenues necessarily diminish during the transitory period of restoring stocks because catches must be reduced to allow the stocks to rebuild. Whilst this means the stocks can sustain, once rebuilt, far larger catches and revenues there must nonetheless be a foregoing of fishing revenues into the economic system (e.g. fish processing). These foregone revenues are an impact on society, and should be taken into account. While this has not been done here, a method for doing so would need to estimate the value per tonne of each stock that is passed on to the processing sector and wider economy. For instance, a fish landed at port may sell for €1 to fish processors. Of the €1 a certain amount is used to cover costs (e.g. crew costs make up 30–40 per cent) and ideally generate some profit. The fish processors may then sell their processed product for €2; how much is used to cover their employees (and any depreciation costs of their capital) would be the critical factor in determining the scale of investment cover needed for the sector.

Current catches

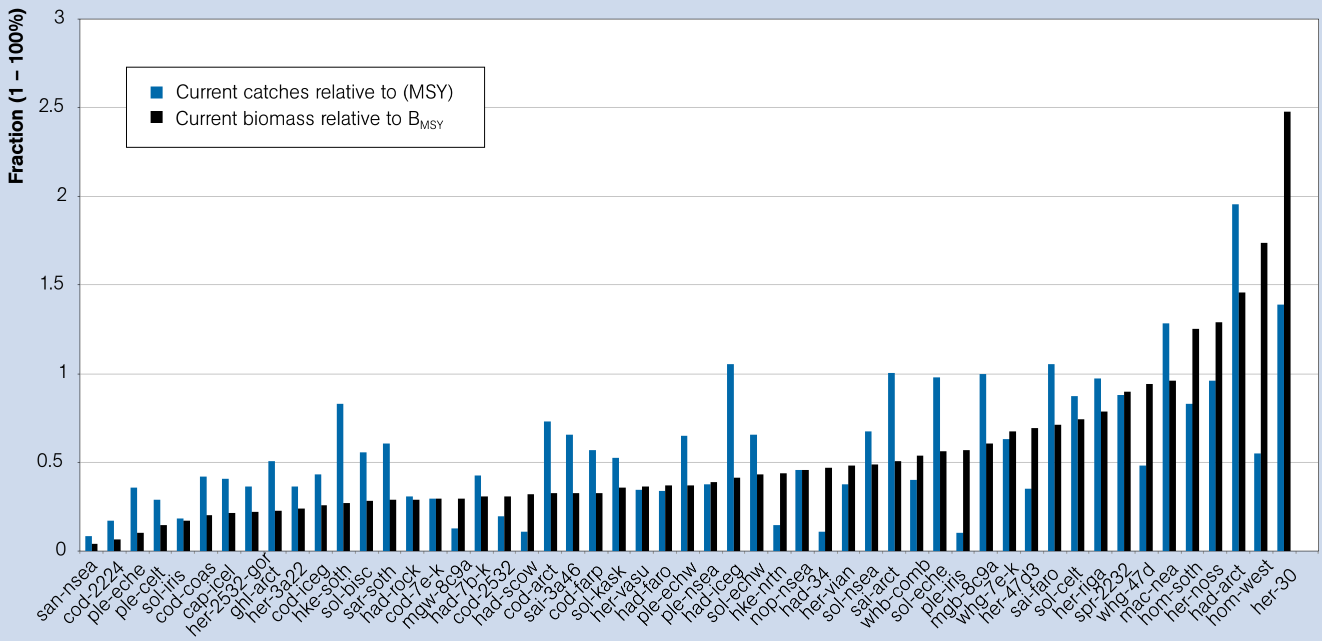
Catches over the 2002-2010 period were estimated in two ways. First, for the purposes of calibrating crew and depreciation costs (as above), the total catches of fleets was calculated from the AER database based on species and fishing area (though in some cases the area was too general to distinguish stocks so ICES stock assessments (2011) were used). Second, we found that this database contained significantly smaller catches than were reported or estimated by ICES. Given that our estimates of required investment for restoring stocks depend on past catches, this would lead to an underestimation of the investment required: fewer catches reported, smaller investment needed. To address this problem we calculated the average costs (as above) for all countries in the AER data, and applied this to all unaccounted catches as reported in the ICES database. These figures are classed as 'Other' in the figures and tables of the report, but may actually be based upon significant EU catches as well as non-EU catches (e.g. on Norway, Iceland, Japan, etc).

Table A4: Catch weights and stock biomass, in tonnes, relative to their sustainable maximum (MSY and B_{MSY}, respectively)

Fish stock	Current biomass	B_{MSY} estimate	Current biomass to B_{MSY} ratio	Current landings	MSY estimate	Landings to MSY ratio
her-30*	571339	230511	2.48	62564	51579	1.21
her-3a22	97452	401717	0.24	81088	116470	0.70
her-2532-gor	526291	2382591	0.22	116755	372837	0.31
her-riga	75748	96519	0.78	36950	30927	1.19
her-47d3	1301092	1881612	0.69	407056	529790	0.77
her-noss*	7862000	6093033	1.29	1146734	1515458	0.76
her-vian	80998	168643	0.48	28370	59344	0.48
her-vasu	218000	599014	0.36	107667	126943	0.85
sar-soth	174000	607521	0.29	98118	147329	0.67
spr-2232	722000	804637	0.90	366667	388386	0.94
cod-2224	29144	453708	0.06	23157	83634	0.28
cod-2532	308787	997248	0.31	57719	255735	0.23
cod-farp	29801	90452	0.33	14971	22267	0.67
cod-7e-k	11944	40638	0.29	5579	10889	0.51
cod-347d	54721	2535687	0.02	61763	373543	0.17
cod-coas	36579	179494	0.20	27222	54805	0.50
cod-iceg	362246	1395544	0.26	190967	388103	0.49
cod-arct	1310681	4039445	0.32	550763	837049	0.66
had-34	235072	499482	0.47	59902	259119	0.23
had-7b-k	31800	103416	0.31	13911	23351	0.60
had-arct*	413258	283337	1.46	165554	127387	1.30
had-faro	20496	55579	0.37	15861	15317	1.04
had-iceg	97480	236781	0.41	83344	61024	1.37
had-rock	13036	44974	0.29	6147	11037	0.56
had-scow	20778	65004	0.32	14193	22745	0.62
whg-7e-k	41900	62321	0.67	11757	13421	0.88
whg-47d	208688	221793	0.94	19438	45767	0.42
whb-comb	2369530	4421365	0.54	1592920	1344398	1.18
sai-3a46	168811	514721	0.33	112678	156804	0.72
sai-arct	358114	706123	0.51	179054	192951	0.93
sai-faro	110529	155547	0.71	55692	41624	1.34
nop-nsea	186149	405855	0.46	43489	275585	0.16
hke-nrtn	145900	332667	0.44	40339	64312	0.63
hke-soth	27700	102177	0.27	13811	20410	0.68
cap-icel	411000	1891858	0.22	431778	957459	0.45
san-nsea	456000	12022105	0.04	342592	3259558	0.11
hom-soth*	238339	190046	1.25	23465	32721	0.72
hom-west*	2579550	1483793	1.74	169260	370376	0.46
ple-celt	1110	7636	0.15	474	1499	0.32
ple-eche	4342	42617	0.10	4993	8810	0.57
ple-echw	3371	9080	0.37	1327	1883	0.70
ple-iris	11100	19471	0.57	706	3586	0.20
ple-nsea	522891	1347588	0.39	111644	162123	0.69
ghl-arct	35749	157120	0.23	15554	31023	0.50
mgb-8c9a	4018	6595	0.61	1021	1302	0.78
mgw-8c9a	962	3227	0.30	135	644	0.21
sol-bisc	13391	46942	0.29	4495	7107	0.63
sol-celt	4187	5635	0.74	1043	989	1.05
sol-eche	14760	26224	0.56	6375	4496	1.42
sol-echw	2571	5972	0.43	961	1051	0.91
sol-iris	1276	7432	0.17	629	1494	0.42
sol-kask	1944	5406	0.36	736	1028	0.72
sol-nsea	36550	74477	0.49	15322	18742	0.82
mac-nea	2907000	3022202	0.96	656160	676655	0.97
Average			0.52			0.68
Average of overfished stocks			0.40			0.66

*Stocks where current biomass > B_{MSY} are not considered overfished. *Source:* Own calculations based on source data.[67,68]

Figure A1: Current biomass (B_{MSY}) and catches relative to their respective maxima (B_{MSY} and MSY) for all 54 stocks. Data sources.[69,70]



In some cases, even the ICES stock database was insufficient for this study, due to a lack of data for certain stocks. For these stocks, namely herring and megrim stocks, the ICES stock assessments (2011) were used instead.[71]

Catches over the 2011–2012 period, which are currently unknown, were estimated as an average of past catches (2002–2010) and also assumed to represent a continuation of the status quo (were there not to be a transition).

Catch weights and stock biomass (both in tonnes) are shown in Table A4 relative to their maximum potential (MSY and B_{MSY}, respectively).

The total landing value of catches was primarily estimated also using the AER database. Where landing values were not available for certain countries (notably Spain), the catch weights were multiplied by prices per tonne instead. The same method was used for catch values from individual stocks. All residual catches declared in ICES but not accounted for in the AER were valued under the 'Other' category (which may include significant EU catches, as well as those of Norway, Iceland, and other countries) by multiplying catch weights from ICES by a price per tonne. A small minority of stocks also showed some discarding in the 'Other' category, meaning that estimates of current landing values are likely to be slightly overestimated.

Another approach that was tried was to multiply all catch weights by a price per tonne – as was done for Spain. The differences between the estimates of aggregate values for the 2002-2010 period by using each method are shown below (Table A5).

Benefits of restoring stocks

The value of stocks fished at MSY was calculated by multiplying the estimates for MSY[72] each stock, as provided by Froese and Proelß,[73] by their price per tonne in 2011 prices. Prices were ascribed according to species, so that multiple stocks of the same species have the same price (see '*Prices and inflation*' section). The price per tonne was calculated in nominal terms by dividing the total value of landings per stock by their respective value using data from the AER.[74] These values were then converted to 2011 prices by adjusting for inflation using data from the ECB.[75]

Table A5: Two methods for estimating catch value estimates for all stocks by all countries are contrasted. The first row (Method 1) shows the results that were used, calculated by using the landing value from the AER, except for Spain and non-AER catch weights which were estimated by multiplying their catch weights by a price per tonne. The second row (Method 2) shows similar results, obtained by simply multiplying all catch weights by a price per tonne (the approach used for stock estimates for each country). This illustrates that data gaps lead to an average difference in current catch value estimate of around €1.2 billion. Figures are rounded.

	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*Average*	*Standard deviation*
Method 1	8538	7522	10150	7763	7424	6252	5207	4334	6184	7042	1763
Method 2	8698	8032	10601	9090	8775	7811	7071	6134	7687	8211	1281
Difference	-160	-510	-452	-1326	-1351	-1559	-1864	-1799	-1503	-1169	482

Source: Own calculations.

Table A6: Transition versus no transition scenarios. The present value of investment fund diminishes over time (9.4 years) from €3 billion to €19 million. Simultaneously, the value of catches increases and begins to outweigh the investment required within just three years. Compared to the status quo of no transition, the net benefits are €69bn - €11bn - €54bn = €5.13bn over the transition period alone (not forgetting the benefits beyond the transitory period). Values in 2011 real terms (though no future inflation accounted for). All values discounted at 3.5 per cent per year. Figures are rounded.

Year	*Transition*		*No Transition*
	Investment Required (mEUR)	*Value of catches stocks (mEUR)*	*Value of catches (mEUR)*
2002		8538	8538
2003		7522	7522
2004		10150	10150
2005		7763	7763
2006		7424	7424
2007		6252	6252
2008		5207	5207
2009		4334	4334
2010		6184	6184
2011		7042	7042
2012		6803	6803
2013	2948	1061	6573
2014	2664	1559	6351
2015	2384	2278	6136
2016	1625	4645	5929
2017	567	9123	5728
2018	125	11953	5535
2019	87	11783	5347
2020	77	11435	5167
2021	60	11114	4992
mid-2022	19	4458	1992
Total discounted value (2013-mid-2022)	10556	69410	53750
Total discounted value (2013-2052) - 40 years	10556	298661	149547

Source: Own calculations

This approach differs from the one taken in the **nef** report *Jobs Lost at Sea* in several respects. First, more stocks are covered in this paper (54 as opposed to 43). Second, the restoration value is only estimated for those stocks which have a positive rebuilding time (i.e. their biomass is smaller than B_{MSY}) (49 out of 54), and then based on the value of MSY (MSY landings multiplied by price). This means that the level of current catches plays no role in the potential value of stocks or rebuilding potential, except through its impacts on biomass level (and thus rebuilding time) (although the difference between current and potential landings indicates the net gain of stock rebuilding). In the report *Jobs Lost at Sea*, although MSY was valued the same way, the value of rebuilding was instead based on the difference between current catches and MSY and no use was made of the biomass level: catches smaller than MSY indicate either previous overfishing or a current under-exploitation of the resource (in which case, revenues are equally foregone), and catches larger than MSY indicate current overfishing (regardless of biomass size). Finally, the prices were calculated differently, with quite different results (Table A8).

Net Present Value (NPV) was calculated as the net gain in fishing revenues (the difference between MSY values and the average landing value during the period 2002-2010) minus the investment cost, over a defined time period.

The return-on-investment (RoI) was calculated as the net gain in fishing revenues (the difference between MSY values and the average landing value during the period 2002-2010) divided by the investment cost, over a defined time period (e.g. the transition period or a 40-year period).

Table A7: Prices (€) per kg for each species in each year of the period 2002-2010. Prices adjusted for inflation. Figures are rounded. Source: Own calculations.

Species	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*Average price (€) per kg*	*Standard deviation*
European plaice	2.13	2.27	1.91	1.96	2.14	2.22	2.14	1.79	1.65	2.024	0.165
Common sole	11.55	11.74	12.18	12.95	13.47	13.37	11.20	10.88	11.43	12.085	0.995
Atlantic mackerel	1.63	1.36	1.76	2.09	1.47	1.57	1.57	1.41	1.84	1.633	0.231
Atlantic cod	2.79	3.17	2.39	2.91	2.84	3.10	2.62	2.19	2.06	2.674	0.336
Haddock	1.65	1.77	1.84	1.82	1.88	1.90	1.62	1.38	1.37	1.691	0.175
Atlantic herring	0.48	0.42	0.38	0.39	0.41	0.37	0.51	0.43	0.48	0.431	0.049
European hake	4.48	3.99	4.52	4.64	4.21	4.02	2.97	2.63	2.71	3.797	0.743
Megrim	17.17	2.54	2.39	3.09	3.49	4.57	4.51	3.19	2.05	4.777	4.935
Saithe(=Pollock)	1.14	1.04	1.16	1.06	1.09	1.22	1.05	1.15	1.25	1.127	0.064
European sprat	0.72	0.60	0.50	0.34	0.45	0.49	1.79	0.45	0.39	0.637	0.468
Whiting	1.50	1.48	1.61	1.67	1.71	2.04	1.50	1.46	1.26	1.581	0.192
European pilchard(=Sardine)	1.03	0.82	1.04	0.89	1.01	1.03	1.23	1.05	1.18	1.032	0.122
Greenland halibut	3.72	4.06	4.15	3.66	3.56	3.73	3.82	3.37	4.81	3.875	0.253
Sandeels(=Sandlances) nei	0.95	0.68	1.64	1.46	1.16	1.52	1.02	1.43	1.09	1.218	0.333
Norway pout	0.60	0.37	1.59	0.60	0.77	0.81	0.36	0.41	0.24	0.639	0.403
Blue whiting(=Poutassou)	0.85	0.68	0.97	1.06	1.15	1.00	1.07	1.37	3.12	1.253	0.203
Atlantic horse mackerel	0.77	1.10	1.21	1.08	1.00	1.08	1.36	0.93	1.55	1.120	0.176
Four-spot megrim	2.93	3.76	4.90	8.24	8.18	6.99	6.84	4.12	4.87	5.649	2.074
Capelin	0.29	0.10	2.36	1.44	1.69	1.10		1.05	1.42	1.182	0.783

Source: Own calculations

Table A8: Price estimates resulting from different methods for the 54 stocks used in this report and the 43 used in the Jobs Lost at Sea report. In the current report, a price per species was calculated as the landing value divided by the landing weight for each recorded landing of each species by each country (and gear), as found in the AER, and averaged over the 2002-2010 period. In the report *Jobs Lost at Sea*, a lack of data at that time (the AER was less detailed during the working period of the paper) meant an alternative approach was used, based on the SeaAroundUs Project datasets.[76] It is unknown which database is more robust. N/A = not available. Data sources found in Table A1.

		Sea change		Jobs Lost at Sea	
Stock ID	*MSY (tonnes)*	*Price per tonne (Euros; 2002-2010 average)*	*MSY value (mEuros)*	*Price per tonne (Euros)*	*MSY value (mEuros)*
her-30	51579	430.9	22.2	355.4	18.3
her-3a22	116470	430.9	50.2	355.4	41.4
her-2532-gor	372837	430.9	160.7	355.4	132.5
her-riga	30927	430.9	13.3	N/A	N/A
her-47d3	529790	430.9	228.3	256.7	136.0
her-noss	1515458	430.9	653.0	235.3	356.6
her-vian	59344	430.9	25.6	249.7	14.8
her-vasu	126943	430.9	54.7	118.5	15.0
sar-soth	147329	1031.6	152.0	417.4	61.5
spr-2232	388386	636.6	247.2	294.6	114.4
cod-2224	83634	2674.4	223.7	N/A	N/A
cod-2532	255735	2674.4	683.9	1323.6	338.5
cod-farp	22267	2674.4	59.6	953.2	21.2
cod-7e-k	10889	2674.4	29.1	1950.0	21.2
cod-347d	373543	2674.4	999.0	1660.0	620.1
cod-coas	54805	2674.4	146.6	N/A	N/A
cod-iceg	388103	2674.4	1037.9	1206.9	468.4
cod-arct	837049	2674.4	2238.6	1283.0	1073.9
had-34	259119	1691.4	438.3	1459.9	378.3
had-7b-k	23351	1691.4	39.5	1223.9	28.6
had-arct	127387	1691.4	215.5	1107.3	141.1
had-faro	15317	1691.4	25.9	931.6	14.3
had-iceg	61024	1691.4	103.2	1429.5	87.2
had-rock	11037	1691.4	18.7	1223.9	13.5
had-scow	22745	1691.4	38.5	1223.9	27.8
whg-7e-k	13421	1580.8	21.2	1250.3	16.8
whg-47d	45767	1580.8	72.3	1105.8	50.6
whb-comb	1344398	1252.7	1684.1	534.0	717.9
sai-3a46	156804	1127.2	176.8	657.8	103.1
sai-arct	192951	1127.2	217.5	535.1	103.3
sai-faro	41624	1127.2	46.9	913.5	38.0
nop-nsea	275585	639.4	176.2	N/A	N/A
hke-nrtn	64312	3797.0	244.2	N/A	N/A
hke-soth	20410	3797.0	77.5	N/A	N/A
cap-icel	957459	1181.8	1131.5	301.4	288.6
san-nsea	3259558	1218.5	3971.8	N/A	N/A
hom-soth	32721	1120.3	36.7	687.5	22.5
hom-west	370376	1120.3	414.9	687.5	254.6
ple-celt	1499	2024.2	3.0	N/A	N/A
ple-eche	8810	2024.2	17.8	1724.5	15.2
ple-echw	1883	2024.2	3.8	1223.9	2.3
ple-iris	3586	2024.2	7.3	N/A	N/A
ple-nsea	162123	2024.2	328.2	1724.5	279.6
ghl-arct	31023	3875.3	120.2	N/A	N/A
mgb-8c9a	1302	4777.4	6.2	3599.9	4.7
mgw-8c9a	644	4777.4	3.1	3599.9	2.3
sol-bisc	7107	12085.3	85.9	1364.7	9.7
sol-celt	989	12085.3	12.0	1364.7	1.3
sol-eche	4496	12085.3	54.3	1364.7	6.1
sol-echw	1051	12085.3	12.7	1364.7	1.4
sol-iris	1494	12085.3	18.1	1364.7	2.0
sol-kask	1028	12085.3	12.4	N/A	N/A
sol-nsea	18742	12085.3	226.5	1364.7	25.6
mac-nea	676655	1633.4	1105.3	723.0	489.2
Total	13582886		18193.4		6559.6
Total (overfished stocks)	11485365		16851.1		5766.5

A full table of results comparing the transition versus no-transition scenarios is shown in Table A6.

Prices and inflation

Table A7 shows the prices used in each year for one kilo of that species.

These were calculated by dividing each catch's landing value by its weight, both of which are obtained from the AER,[77] and averaging for the entire year. These were then adjusted for inflation using a previously published (and standard) method.[78]

The price used has significant impacts on the results. In a previous report, we used different (and less direct) methods to estimate prices, and found quite different results. These are contrasted in Table A7.

Past inflation is taken into account following the methodology (and same data sources) outlined in the **nef** report *Jobs Lost at Sea*. Future inflation is not taken into account, but could have been assumed to be the Bank of England target inflation rate (currently 2.5 per cent), at least for UK landings.

Displacement of impacts by imports and alternative stocks

Our model is a highly simplified version of events following a moratorium on the stocks: that fishing stops in these stocks and crews and depreciation costs are covered during the transition. In all likelihood, fishing pressure would to some degree be passed onto other stocks, in turn covering that share of the investment costs. This displacement would reduce the overall size of the investment fund, though to what degree would require a full assessment of fishing opportunities during the transitory years as well as the likely behaviour of the industry.

Furthermore, expanding the investment fund to cover short-term lost employment impacts in the processing sector (and other jobs dependent on the status quo level of fishing) would need to account for the potential displacement of fishing other stocks, or a change in imports for processing.

Discounting and time period

The impacts of the transition are estimated over 40 years. If managed sustainably, fish stocks clearly do not have a time limit, and the benefits of sustainable fishing would continue to accrue indefinitely. We place a 40-year limit to be conservative in our results and also to recognise the unquantified uncertainty in the MSY estimates, societal choices, predictability of the fishing fleet's behaviour, and so forth.

The discount factor is calculated as:

$$D_n = \frac{1}{(1+r)^n}$$

Where D_n is the discount factor, r is the discount rate, and n is the year number. The discount rate used was variable, set according to the Treasury Green Book[79] (3.5 per cent for years 0–30, and three per cent for years 31–75). Applied to an annual value (cost or benefit) , in period , its present (discounted) value (PV) is:

$$PV = D_n \,.\, X$$

And, if the annual value accumulates over a projected 40 years then its total discounted value, with the variable discount rate above, is:

$$\sum_{n=0}^{40} D_n \,.\, X = X \,.\, \sum_{n=0}^{40} D_n = X \text{ x } 22.906$$

If the annual value is different each year then this instead becomes:

$$\sum_{n=0}^{40} D_n \,.\, X_n$$

Caveats and future research

The following is a non-exhaustive list of ideas for how future work could further develop this study.

- Estimates of recovery time are based on the logistic curve. This assumption on fish stocks growth is made for convenience but is not necessarily the best estimate of growth for every fish stock. Curves with better fit could be used, as found from the ICES stock assessments and working groups.

- Estimates of MSY were entirely based on a paper by Froese & Proelß.[80] To improve their robustness, their 95 per cent confidence values could also have been used in this study, as well as other MSY estimates in the literature. In cases where the applicability of MSY estimates is disputed then alternative methods or management goals could be used.

- Discrepancies between the ICES catch, ICES stock summary and the Annual Economic Report databases exist for a number of variables, particularly, in our case, the weight of landings. Which to use for each stock depends on the reliability of the data, which itself would require substantial effort to deliberate on. A starting point could the databases held by member states.

- Disaggregation of the 'Other' class to attribute transition investment and benefits, as well as employment impacts, to specific countries, particularly EU27 countries is an important though laborious task. This requires checking all stock assessments for landing and discard rates for each stock to complement the ICES and AER datasets. Similarly, the exercise would help estimate the current and future discard rates in order to deflate the total values to reflect market prices more accurately.

- The price elasticity of demand was set to infinity: no change in price occurs with a change in quantity. Other values could have been used, for example to alter the price by a fixed proportion depending on either demand or supply (though conventional elasticities of demand of 0.2 would be inadequate for stocks with rebuilding potential of more than 100 per cent).

- The 54 stocks in this study were those for which MSY estimates were available. However, none of these are located in the Mediterranean. Without stocks in this area included it is difficult to have an accurate view of the EU-wide investment required.

- A significant improvement would be in capacity considerations. This study attempts to keep separate the discussion about appropriate capacity and the economic case for rebuilding fish stocks. As such, its 'neutral' stance is to maintain current capacity – no government 'buy backs' for vessels, nor purchasing of new ones, are considered. In a sense, this assumes that all current capacity is sufficient to catch the larger quantities of fish in the future, with stocks rebuilt. Even if this were possible, it may not be society's best option since it would promote profitability and capital efficiency over employment and coastal communities. The socially optimal trade-off between the two could be proposed through scenario analysis, as well as its implications for optimal fleet size and respective transition costs and benefits.

- The transition path used here to restore stocks is conventionally known as the 'most rapid approach path' (MRAP).[81] This is typically a socially optimal choice if the discount rate is very low (i.e. zero), so that the future is weighed equally with the present. Other approach paths could be modelled dynamically based on non-zero discount rates.

- Moratoria on the 49 (out of 54) overfished stocks are likely to require significant monitoring and enforcement. This is not considered in this paper, but could be modelled in future work.

- During the moratoria it is expected that fishermen will not be fishing. The financial cover to compensate their temporary foregone income assumes that they have no alternative forms of employment (no 'opportunity costs'). In reality, in the current context of high unemployment, it would be more socially useful for fishermen to be employed by the investment fund for other activities, whether it is engaged in monitoring and enforcement, data collection for scientific stock assessments, removing waste from the sea, or moving into entirely different non-seafaring jobs. It is not the purpose of this report to speculate or propose their other options but it would be a necessary component of any policy action.

Endnotes

1 Strictly, Net Present Value (NPV), which is the value in today's money of a series of (profit) payments running into the future.

2 Though, it is also worth noting an improvement to 47 per cent in 2012. Source: European Commission (2012). Communication from the Commission to the Council concerning a consultation on Fishing Opportunities for 2013 in COM(2012)278 final. Brussels: EC.

3 The State of World Fisheries and Aquaculture. (2012). FAO Fisheries and Aquaculture Department, Food and Agriculture

Organization of the United Nations, Rome, 2012. Retrieved from: http://www.fao.org/docrep/016/i2727e/i2727e00.htm

4 Evidence now exists for the role of at least the following factors in reducing the biocapacity of the Oceans to continue providing services:

Climate change impacts on fish populations:

Perry, A. L., Low, P. J., Ellis, J. R. & Reynolds, J. D. (2005). Climate change and distribution shifts in marine fishes. *Science*, 308:1912–1915.

Worm, B. & Myers, R. A. (2004). Managing fisheries in a changing climate. *Nature*, 429:15.

Ecological collapse and regime shifts:

Biggs, R., *et al.* (2009) Turning back from the brink: Detecting an impending regime shift in time to avert it. *P Natl Acad Sci USA*, 106:826-831

Steffen, W., *et al.* (2007) The Anthropocene: Are humans now overwhelming the great forces of nature. *Ambio*, 36:614-621.

Biodiversity loss:

Dulvy, N.K., Sadovy, Y. & Reynolds, J.D. (2003). Extinction vulnerability in marine populations. *Fish and Fisheries*, 4(1):25–64.

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: biodiversity synthesis. 87

And planetary boundaries:

Rockström, J. Steffen, Noone, K., Persson, A., Stuart Chapin, F., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen , P.& Foley, J.A. (2009) A safe operating space for humanity. *Nature*, 461:472-475. doi:10.1038/461472a.

5 Own calculations: (Current landings x price per tonne)/(MSY x price per tonne) based on:

Estimates of MSY from Froese, R. & Proelß, A. (2010) Rebuilding fish stocks no later than 2015: will Europe meet the deadline? *Fish and Fisheries*, 11(2):194–202. Supporting information. DOI: 10.1111/j.1467-2979.2009.00349.x.

Estimates of current landings from Anderson, J., Guillen, J. & Virtanen, J. (2011). The 2011 Annual Economic Report on the EU Fishing Fleet (STECF-11-16). European Commission Joint Research Centre. Final EUR 25106 EN - 2011. Luxembourg: European Communities.

Prices cancel each other in the calculation, so that the ratio holds also for catch weights.

6 HM Government. Marine Strategy Framework Directive consultation. UK Initial Assessment and Proposals for Good Environmental Status. March 2012. Defra: London. Retrieved from: www.defra.gov.uk/consult/2012/03/27/marine-strategy-framework-1203

7 Over the period 2003-2012. Source: European Commission (2012). Communication from the Commission to the Council concerning a consultation on Fishing Opportunities for 2013 in COM(2012)278 final. Brussels: EC.

8 O'Leary, B.C., Smart, J.C.R., Neale, F.C.,Hawkins, J.P., Newman, S., Milman, A.C., Roberts, C.M. (2011). Fisheries Mismanagement. *Marine Pollution Bulletin*, 62(12):2642–2648.

9 Subsidies are from the Financial Instrument for Fisheries Guidance (FIFG), the European Fisheries Fund (EFF), and the European Maritime and Fisheries Fund (EMFF). Multiple references:

For subsidies 2000-2006: Bevins, K. & Sporrong, N. (2002) Subsidies to the European Union Fisheries Sector. London: Institute for European Environmental Policy.

For subsidies 2007-2013: EFF Fact Sheet. Retrieved from: http://ec.europa.eu/fisheries/cfp/eff/index_en.htm

For subsidies 2014-2020: European Commission: A new European Fund for the EU's Maritime and Fisheries Policies. Retrieved from: http://ec.europa.eu/commission_2010-2014/damanaki/headlines/press-releases/2011/12/20111202_en.htm

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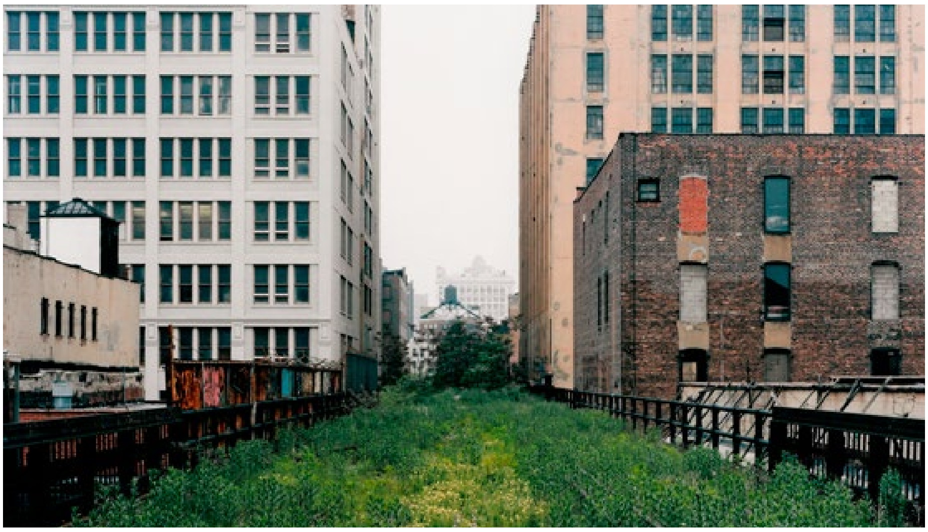

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