Let's bring back the salmon, sea birds and G6 mackerel!

THE HYPOTHESIS ON OVERGRAZING AND PREDATION

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Version 26th June 2018

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Foreword

The Hypothesis on Overgrazing and Predation by Mackerel in the northeast Atlantic.

The JCH hypothesis claims that unprecedented numbers (literally billions) of mackerel are competing with European salmon post smolts (approx. 10-15 million) for food and predating on them as opportunities arise. The collapse in numbers of salmon (to about 5%) returning to their native rivers points to a massive mortality at sea. The coincidence of the explosion in timing, density and range of mackerel numbers with the sharp decline in returning salmon provides a possible and feasible explanation. Our knowledge of salmon migration routes and where they overlap with massive mackerel shoals leads to an assumption that overgrazing by billions of mackerel could leave little food for young salmon.

At the same time both mackerel and salmon post smolts show signs of starvation and severe loss of condition. With faster growing mackerel using the same sea space as salmon smolts throughout their migration, opportunities for predation by mackerel are frequent

I asked Dr Holst if he would allow me to write this foreword to his hypothesis from the viewpoint of someone who has worked closely with scientists, managers, anglers and people who depend on wild salmon for their livelihood or lifestyle. I am not a scientist myself. I am however an experienced salmon fishery manager and angler. My time working with the AST introduced me to the tumultuous world of salmon politics, dominated by traditional netting (now largely gone), the salmon aquaculture industry and the salmon angling tourism industry. Before I continue, I must explain that Dr Holst's sole aim is for his hypothesis to be tested.

Dr Holst's calculations on current abundance of mackerel in the northeast Atlantic region challenge official ICES estimates. Basing his thinking on official figures, and on his own observations and those of fishing vessel crews in the region, he believes that mackerel numbers are being severely underestimated, perhaps by a factor of six or more, and that this has led to dangerously low mackerel fishing quotas over years.

Mackerel are now more numerous than ever before according to recent reports quoted in Dr Holst's paper. Their range now extends into areas such as the southern tip and east coast of Greenland, around Iceland, Jan Mayen Island and Spitzbergen, where they have never been recorded before.

Impacts on other species. Resulting overgrazing of zoo plankton species has impacted on other pelagic fish species. Certain species of plankton and small fish-eating birds, such as kittiwakes and puffins, have also been negatively affected. Dr Holst also surmises that the explosion in mackerel abundance in northern areas has led to the large fish-eating gannet showing strong population growth and establishing colonies in new areas, such as Bear Island, from where they can now predate on mackerel.

I first met Dr Jens Christian Holst in the company of the AST's Research Director, Dr Richard Shelton, at the 2008 NASCO conference in Asturias. The SALSEA-MERGE project, for which Dr Holst became co-ordinator, was about to become the first multinational effort under the NASCO banner to explore the lives of salmon at sea. Dr Shelton and Dr Holst had previously worked together on sampling salmon post smolts at sea. They were jointly responsible for designing and testing an open-ended trawl that enabled photos to be taken of salmon as they passed through an open trawl. Those early sampling cruises provided evidence that mackerel and post-smolt salmon are included in species overlaps during their northern, late spring migration west of the British Isles.

Dr Holst's experience of studying interactions between pelagic fish species in their marine environment is the basis of a practical approach to studying the lives of salmon at sea. By combining data coming from marine research vessels with the experiences of sports and professional fishermen he adopts an integrated scientific methodology. That ecosystem-based approach has become the baseline for his hypothesis that there is now a serious imbalance among pelagic fish stocks, caused by the dominance of mackerel overgrazing and predating on other juvenile fish species, such as salmon post smolts.

An ecosystem-based approach demands taking into account all factors that could possibly influence recruitment, growth and survival of different species. Sea temperature and atmospheric pressure for example are critical influences acting as 'conductors in the ecological orchestra' in which all pelagic fish play varied roles at different stages in their life histories. The role of commercial fishing to manipulate fish stocks to achieve a more balanced food web is also of crucial importance. This mechanism is routinely used, for example in livestock production, deer management and trout lake management

If the JCH Hypothesis leads to the conclusion that huge shoals of mackerel are severely damaging the pelagic food web in areas of the northeast Atlantic Ocean it will become necessary to reduce their numbers through an internationally agreed and closely monitored thinning fishery. How that might be achieved is the subject of a discussion to be held later, if and only if the hypothesis is shown to be valid.

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Chapter 1

Background

Wild salmon stocks from in particular the European southern NEAC salmon area are dwindling and today for instance most Irish and Northern Irish rivers are closed for 'normal' fishing. Hypotheses on the marine factors underlying the salmon collapse are many: marine climate, sea lice from salmon farms, inbreeding of escapees in wild salmon stocks, disease and bycatch in pelagic fisheries.

The 2017 ICES Working Group on North Atlantic Salmon, ICES WGNAS, is clear in its conclusions: '*The continued low abundance of salmon stocks across North America, de-spite significant fishery reductions, strengthens the conclusions that factors acting on survival in the first and second years at sea, at both local and broad ocean scales are constraining abundance of Atlantic salmon'.*

In parallel with the collapsing European salmon stocks a collapse has been observed in western European sea birds eating plankton and small fish, like the kittiwake and puffin. The salmon and these types of sea bird have in common that they are direct and indirect competitors with mackerel for food.

We have also seen a degrading of the quality of the mackerel fished in the northeast Atlantic at least over the last ten years, for instance with the so-called G6 quality more or less disappearing from the catches. G6 is mackerel above 600 grammes that is highly regarded and well paid in the Japanese market. In general, there are more and more negative signals coming out of the markets about the degrading quality of the northeast Atlantic mackerel leading to more and more severe consequences for the fishing industry.

As a marine fisheries scientist, I have worked closely on the marine ecology of salmon and the factors affecting marine survival of Atlantic salmon since 1991. Based on my ecosystem-based research in the NE Atlantic, I have developed the hypothesis that overgrazing and predation are major factors behind amongst other dwindling salmon and sea bird stocks, and the deteriorating quality of mackerel fished in western Europe.

Based on what I consider to be strong empiric evidence, the NE Atlantic mackerel stock has grown totally out of proportion due to gross underestimation, leading to overly cautious fishing quotas and underfishing as a consequence. Because of this very large mackerel stock, the food resources of whales, seals, sea birds, salmon, other pelagic fishes and the mackerel itself are now heavily overgrazed. Today, a 7-year-old mackerel weighs half of its weight of 10 years ago — a clear sign of the overgrazing and lack of food. This is only one of many signs of an ecosystem totally outside its 'natural range'.

This lack of food has also lead to starvation and very slow growth of young salmon at sea, the salmon postsmolt. Postsmolts are now more vulnerable to predation and other natural mortality than before the mackerel 'explosion'.

This document presents the hypothesis on overgrazing and predation with a focus on the effects on western European salmon and sea bird stocks, but also mentioning other ecologic and economic effects. Because underestimation of the NE Atlantic mackerel stock forms an important basis for the hypothesis, I present data and argue in chapter 2 of this document that ICES at present dramatically underestimate the NE Atlantic mackerel stock.

The hypothesis on overgrazing and predation

The development of the hypothesis on overgrazing and predation started around 2005. It has been a dynamic process where new observations and data have been included along the path. Looking through the talks on Researchgate.com that I have given on the subject since 2008 this is evident. The development of the hypothesis will continue forwards. Today it reads:

a) Over a long time, a systematic underestimation of the pelagic fish stocks in the Norwegian Sea has occurred, especially in mackerel and herring but probably also blue whiting. This has resulted in systematically too low quota advice and too low fishing levels. The stock growth in the pelagic fish stocks in the Norwegian Sea and neighboring areas has consequently been larger than we have been aware of for a long time.

b) Too large stocks of pelagic fish have led to a strong overgrazing of the zooplankton and juveniles/small fish in the Norwegian Sea and adjacent coastal and marine areas. The recommended quotas have not been ecologically sustainable.

c) Due to the mackerel's strong population growth, its opportunistic character and high migratory potential, it has increased its spawning and grazing areas dramatically.

d) In parallel with the decreasing plankton resources, the mackerel has compensated for the reduction in the plankton food source by changing its feeding habits to eat more juveiles/small fish like larvae and 0-group of Norwegian spring spawning herring (NSSH), capelin at Jan Mayen Island, sprats in the Norwegian fjords, sand eel and salmon post smolt in the early sea phase.

e) The strong grazing pressure from the mackerel stock has consequently a serious negative impact on many species today, both through direct and indirect competition for food and through predation.

f) The strong down-grazing of zooplankton that grazes the plant plankton has led to a strong reduction in the general grazing on the plant plankton. Therefore, today much of the plant plankton dies off and sinks to the bottom rather than being eaten by the zooplankton.

g) Because of the energy from the plant plankton lost to the bottom we see that the total productivity of the Norwegian Sea ecosystem is greatly reduced and more and more stocks in the upper part of the ecosystem are deteriorating (Figure 1).

h) Examples of this deterioration are collapses in many zooplankton and small fish-dependent sea bird stocks, collapse in European salmon stocks, collapse in the individual growth of the mackerel stock and collapses in local herring, sand eel and sprats stocks on the Norwegian coast. We also for instance observe a strong reduction in the blubber thickness of the minke whale, a change from Norwegian Sea feeding to Barents Sea feeding for fin whales in summer and changes in the sperm whale's feeding habits outside Vesterålen in northern Norway during summer.

i) The lowered ecosystem productivity also give a lowered output for the fisheries, for instance reflected in lack of large and high quality mackerel and low recruitment in the Norwegian spring spawning herring stock.

j) We have already seen many negative effects of the pelagic fish stocks overgrazing the Norwegian Sea and must be prepared for more and more serious ecologic and economic consequences in the future unless the current trend of overgrazing by mackerel is actively reversed.

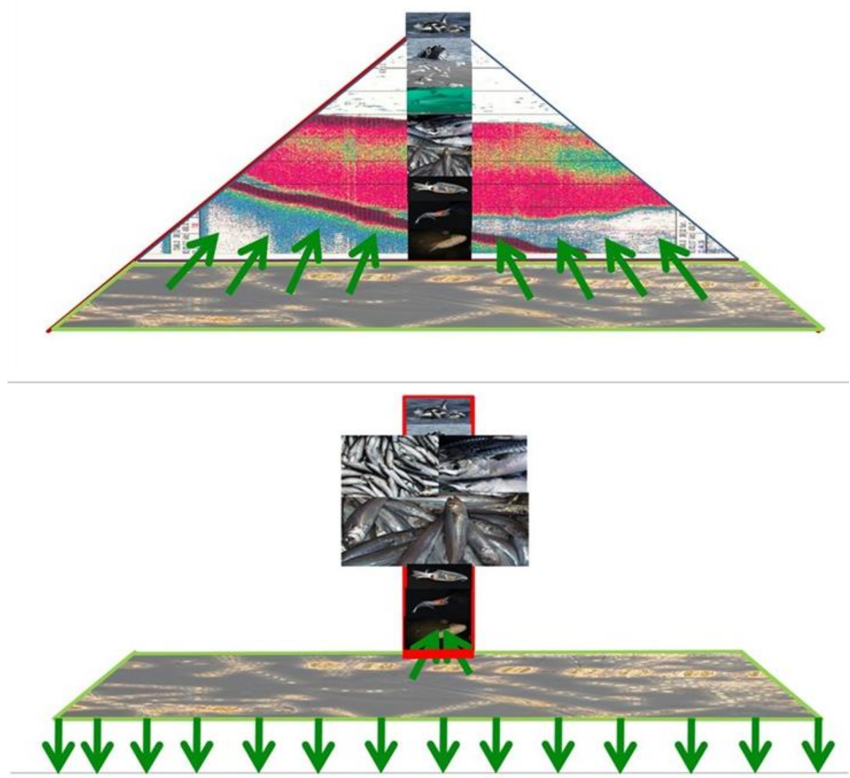


Figure 1. Upper panel: A ‘normal’ pyramid shaped oceanic ecosystem. The green arrows indicate the normal flow of energy from the plant plankton to the zooplankton and upper part of the ecosystem.
Lower panel: A ‘top-heavy’ ecosystem where the pelagic fish grazing capacity is too large and has overgrazed the zooplankton. This has led to a severely lowered flow of energy from the plants to the upper parts of the ecosystem with grave consequences to the total ecosystem productivity, many species and the harvesting potential of the ecosystem.

Mackerel, a voracious hunters

A 30 cm long mackerel will eat at least a 12.5 cm mackerel meaning a mackerel can eat a fish at least 40% its own length (Figure 2). This again means a mackerel at 50 cm can eat a 20 cm postsmolt salmon. In other words, mackerel today can prey efficiently on postsmolt salmon during much of the postsmolts first summer at sea.

Figure 2: 30 cm mackerel with 12.5 cm mackerel in its stomach. Photo courtesy of Ian Kinsey.

Traditionally, the main spawning grounds of the NE Atlantic mackerel stock were in the North Sea and west of the British Isles. In parallel with the strong stock growth starting around 2003, mackerel spawning areas swelled, particularly in the western areas and northwards towards northern Norway.

The widening of mackerel egg distributions from April-May 1992 (Figure 3) to 2016 (Figure 4) demonstrate the increase of the mackerel spawning stock distribution west of the British Isles. In figure 5 and 6 the observed expansion of the mackerel summer feeding areas from 2007 to 2017 is shown. Both the expansion of the spawning and feeding areas demonstrate the enormous growth of the mackerel stock. From 2008 onwards, mackerel have also spawned in the Norwegian Sea and in Norwegian fjords, as far north as northern Norway (Figure 7).

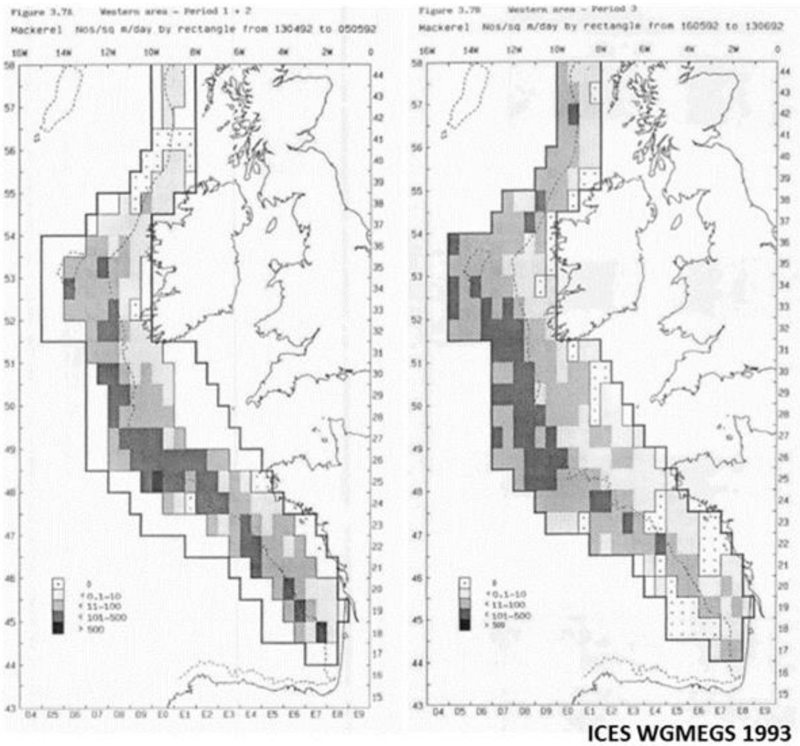


Figure 3: Distribution of mackerel egg, proxy for spawning mackerel, during the period of the Irish smolt run in 1992. Left 13 April – 5 May, right 16 May-13 June.

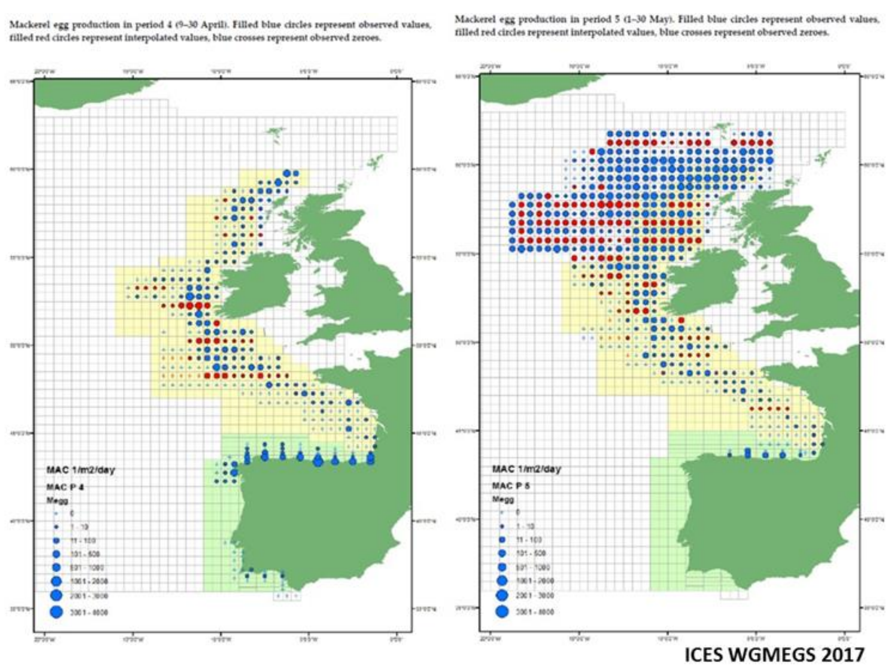


Figure 4: Distribution of mackerel egg, proxy for spawning mackerel, during period of the Irish smolt run in 2016. Left 9-30 April, right 1-30 May. Note that the survey does not find the northern zero line of eggs which correspond well with the observations in figure 7.

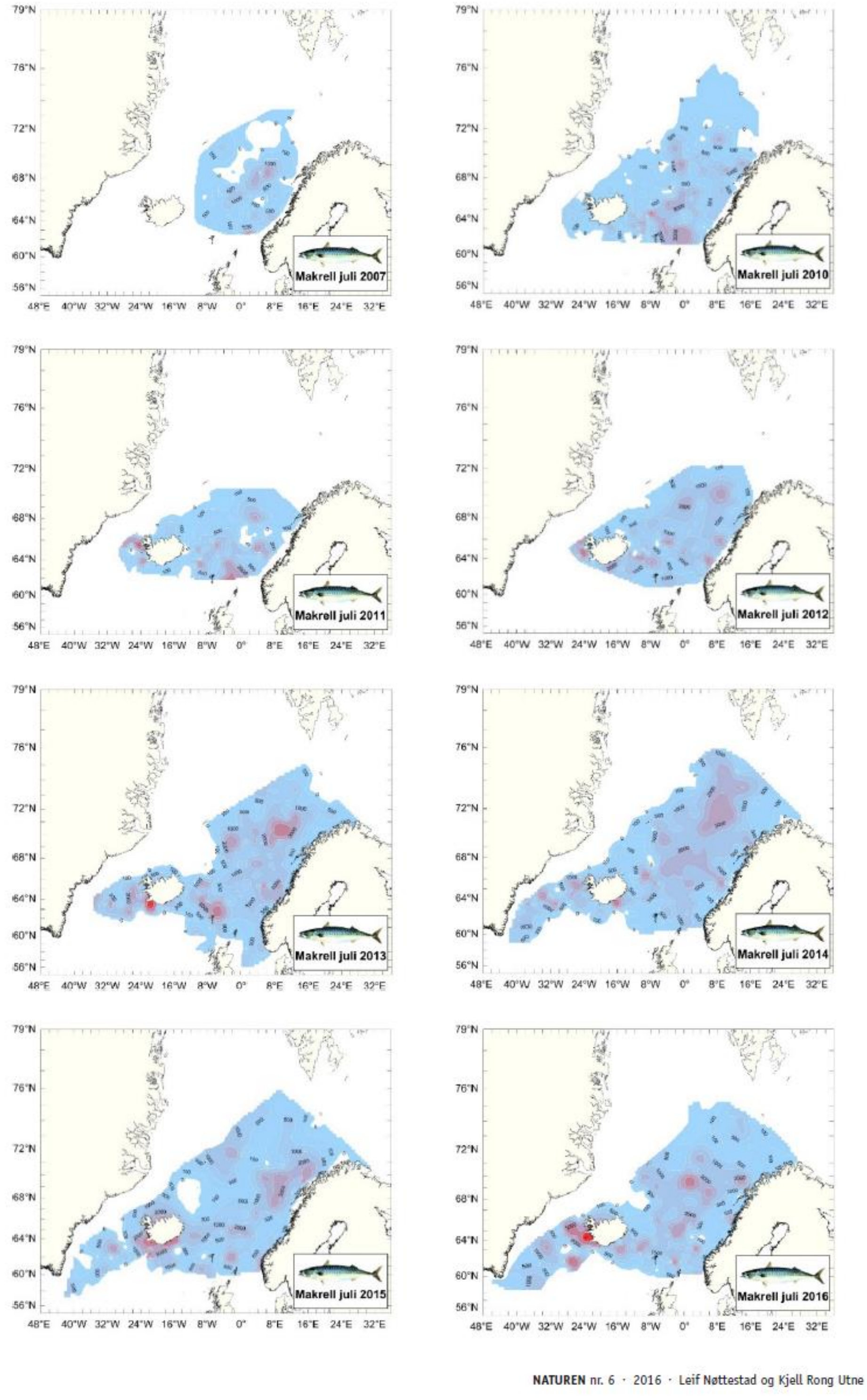
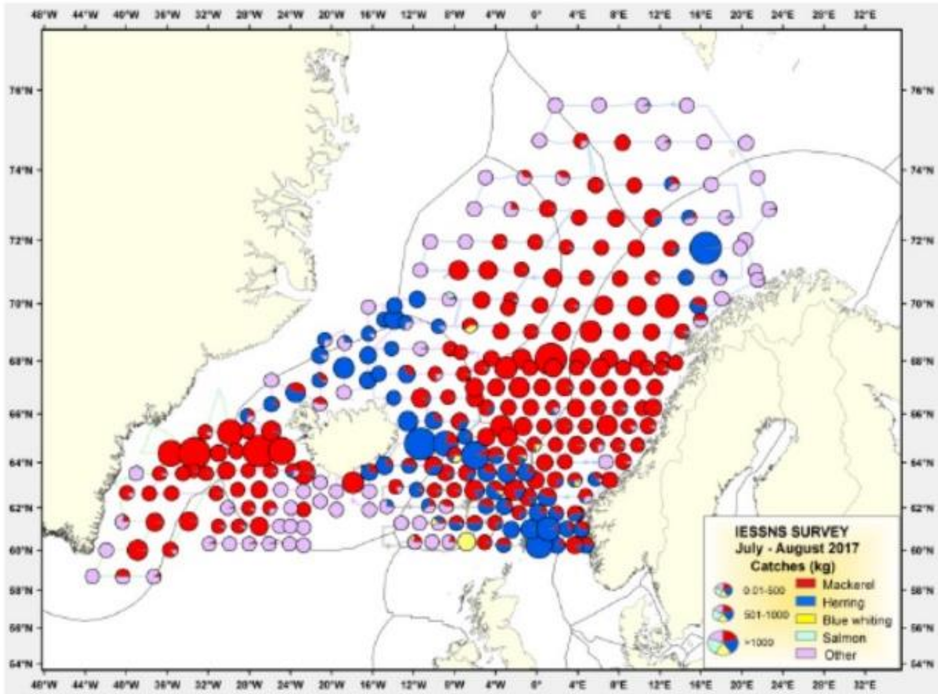


Figure 5. The geographic expansion of the feeding areas of the NE Atlantic mackerel stock as reflected in the ICES IESSNS survey during 2007-2016. The survey runs during July and bit into August. During these ten years the feeding area of the mackerel expanded by a factor of three while den density doubled, indicating a six fold increase in stock size during the period. From Nøttestad and Utne, Naturen nr 6, 2016.



ICES WGWIDE 2017

Figure 6. Trawl stations and catches of mackerel in red during the 2017 ICES IESSNS survey. Blue bubbles are herring catches. The 2017 survey gave the highest spawning stock biomass index ever of mackerel at 10.3 million tonnes, demonstrating the continued stock growth from 2016. As seen from the map there are large areas in the North Sea, Norwegian fjords, Skagerrak, Kattegat and around the British Isles not covered by the survey, indicating that the survey produces an under estimate. Furthermore, experienced Faroese and Norwegian skippers who have participated in the survey are worried because they see large amounts of mackerel escaping under the trawl, thus not ending up in the spawning stock biomass index.

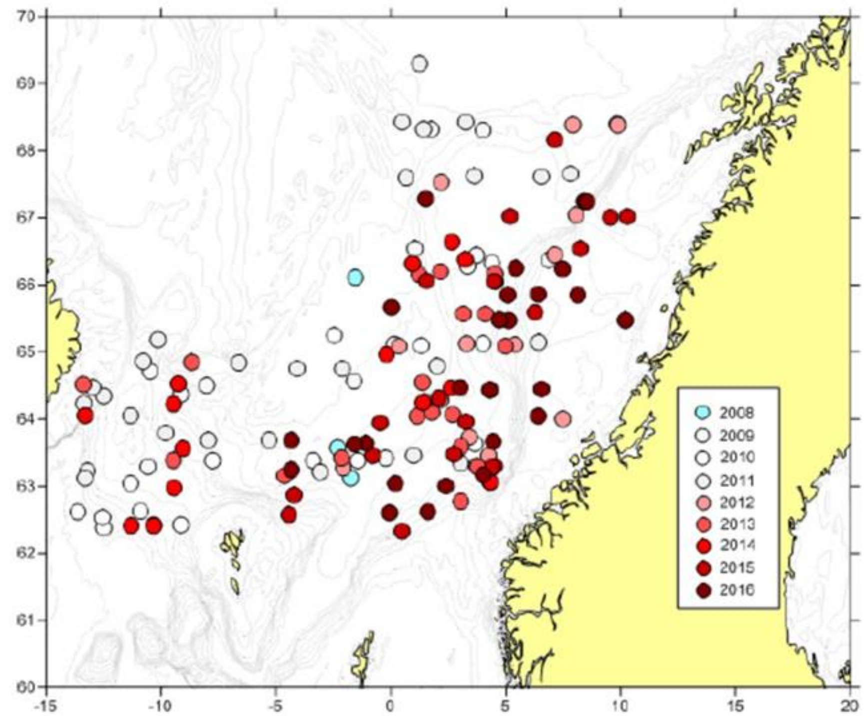


Figure 7. Catches of spawning mackerel during the IESNS surveys in the Norwegian Sea May 2008-2016. Spawning mackerel was never observed in this area before 2008 but has intensified strongly after, both in the Norwegian Sea and in Norwegian fjords way north-east at least to the Norway-Russian border. From ICES WGWIDE 2017.

Overlapping migration routes of mackerel and southern postsmolts

Mackerel and southern European salmon postsmolts both use the shelf edge currents west of the European continent to speed up their northern feeding migration in late spring and early summer. Comparing figures 5, 6, 7 and 8 the geographic overlap between mackerel and postsmolts in late spring and summer is evident.

This ‘co-swimming’ of mackerel and salmon postsmolts during the ‘on average’ about 2,000-kilometre migration from southern European salmon river mouths to north of the Vøring plateau in the Norwegian Sea at 68 degrees north thus creates the perfect predation opportunity for the starving mackerel on the now slow-growing and more vulnerable postsmolts.

Knowing that the migration takes about two months, I leave it to the reader to consider what the effect of the combined effect of competition and predation from mackerel could be today on postsmolts from waters off the island of Ireland, France, Portugal, Spain and western Scotland during this migration period. Mackerel is also abundant in the North Sea and a comparable situation would apply to postsmolts from Wales, England and eastern Scotland.

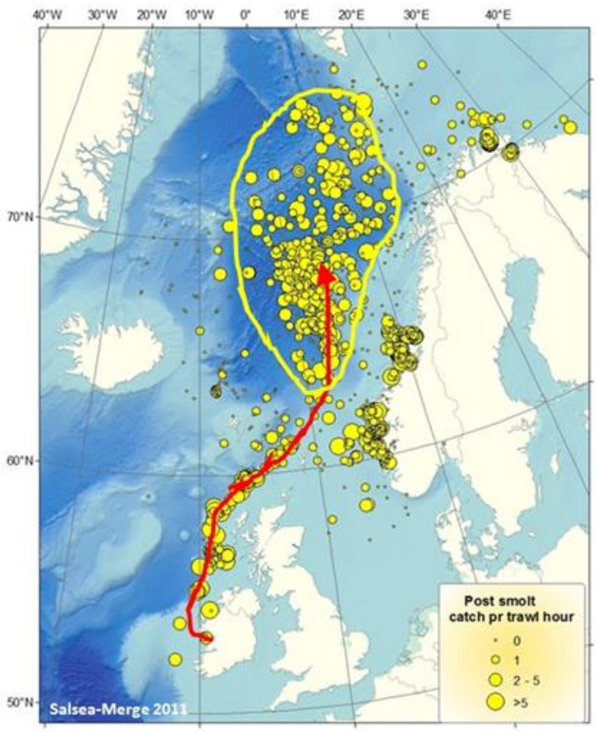


Figure 8. Approximate swimming path of a Corrib postsmolt (red) from western Ireland to its Norwegian Sea feeding area (yellow line). Yellow bubbles are catches of postsmolts made in dedicated salmon trawl hauls during 1991-2011 using the Salmon-Trawl. Note how the postsmolts follow the shelf edge current northwards then spread out in the Norwegian Sea feeding areas, all in parallel with the mackerel as can be seen in the maps above. Original map modified by author.

The salmon stocks in the southern NEAC area have collapsed at much higher and more alarming rates than the Norwegian salmon stocks (Figure 9), despite about 1.3 million tonnes of salmon and rainbow trout being farmed in Norway and only about a total of 200.000 tonnes being farmed in two of the southern regions, Ireland and western Scotland, plus 500 tonnes in Northern-Ireland. All of the southern postsmolts have to ‘co-swim’ northwards with the now very dense concentrations of mackerel, more than double the distance and period compared with the average Norwegian postsmolt.

That said, this is not to defend today’s fish farming practices which I believe are unsustainable and should change to closed or semi-closed containment systems —both from an environmental perspective and not the least in terms of sustainable growth potential for the industry. Sea lice is a factor for the marine survival of salmon in some areas but it is a relatively small factor today, and should not be the point of focus in the recovery of European salmon stocks.

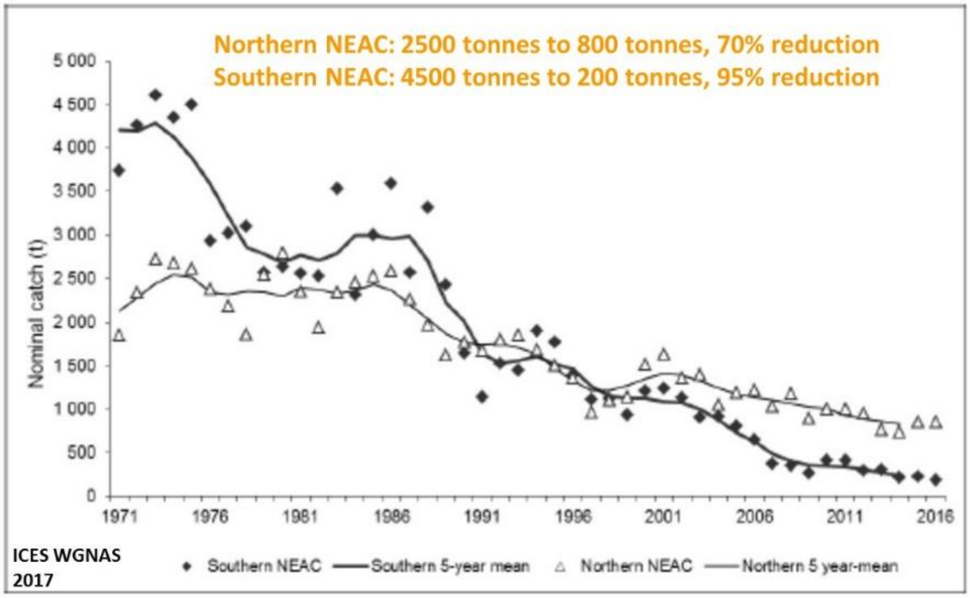


Figure 9. Development of salmon nominal catch in southern and northern NEAC 1971 to 2016. Text at top inserted by author. Filled symbols and darker line southern NEAC.

Figure 10. Examples of the young mackerel currently growing up ‘all over’ the North Sea, Norwegian Sea and along the Norwegian coast at the moment. These were caught in a ‘washing set’ by the purse seiner ‘Brennholm’ at an arbitrary position 100 nm west of the Lofoten Isles in January 2018. At this stage these small mackerels are competitors to the postsmolt salmon, later they will be both competitors and potential predators. The new and abundant availability of juvenile mackerel in the multi sea winter salmon feeding areas may be a good explanation to why the MSW fishes have such a good condition at present despite their poor early sea growth. Photo JC Holst.

Following two years of successful mackerel spawning in 2016 and 2017 in the Norwegian Sea and Norwegian coast, these areas are now 'full' of juvenile mackerel (Figure 10). Consequently, the worst may well be yet to come for the salmon from the southern European salmon regions.

The linked sea bird collapse

In parallel with the European salmon collapse, we have witnessed a collapse of a large range of western European sea birds depending on plankton and fish larvae/small fish as main components in their diets. The worst hit species is probably the surface feeding kittiwake, a small sea gull, which compete directly with the mackerel in its diet. The collapse of the kittiwake has happened in parallel with the mackerel outburst.

At the same time we have seen a strong growth in northern gannets populations, a sea bird eating large fish and with mackerel as an important part of it's diet. It seems nesting locations are restricting their population growth in the western Scottish sea bird cliffs while they have expanded strongly for example in the North Sea on Bass Rock and northwards along the Norwegian Coast and at the Bear Island. The gannet established at the Bear Island few years ago with a 100% nesting success and the colony is growing quickly.

In general sea birds competing for food with mackerel are plummeting in parallel with the growing mackerel distribution and density while sea birds eating mackerel are thriving from the dramatic increase in mackerel availability (Figure 11).

Mackerel, postsmolts and kittiwake have a large overlap in diet, in particular in amphipods, fish larvae and small fishes. The usual explanation for the collapse of the plankton and small fish dependent sea birds is climate change and fisheries. But it is a large paradox that the plankton these sea birds eat is not fished and neither are 0-group fish. But both plankton and 0-group fish are both prime elements in the mackerel diet.

Today sport fishermen see the new immigrant mackerel eating out the unfished local sand eel stocks when they wade out on sand banks in the Lofoten area in northern Norway to fly fish for salmon and sea trout. Earlier these stocks of sand eel were important food for salmon, sea trout and sea birds like kittiwakes. Now they are fading away under the strong predation pressure from mackerel, a species hardly seen in northern Norway before 2008.

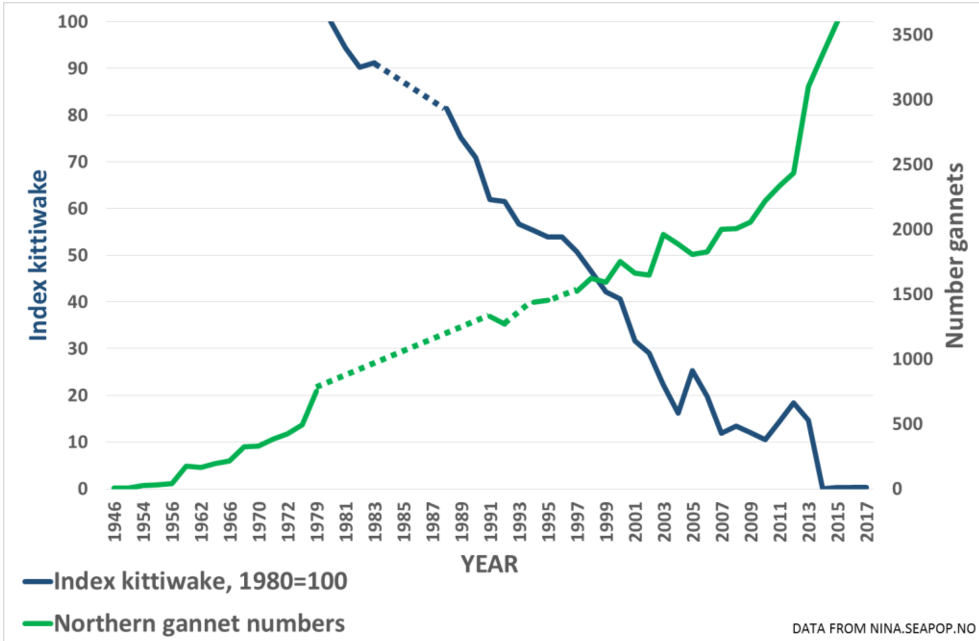


Figure 11. The strongly contrasting development in kittiwake and northern gannets on the Runde seabird cliff off the Norwegian west coast at about 62° north is a good example of how the plankton and small-fish eating sea birds lose out in the competition with the mackerel while the gannet, a mackerel eating sea bird, prosper from it. Following the track of the mackerel outburst from Ireland north to Spitzbergen we can find a comparable pattern repeated over and over again in various sea bird cliffs.

Reasons unknown

Some scientists claim temperature and climate change is the culprit for the European wild salmon collapse. In my view there is no empiric basis for such a conclusion.

If we study water temperatures in the main feeding area of 'southern' European postsmolts in the Norwegian Sea, they rose from the 1970s to 2007 and have now dropped to close to or below normal, according to the Institute of Marine Research (IMR) in Norway.
Figure 12 below describes the development in temperature conditions in the most important feeding areas of European postsmolts during the late spring-summer.

Climate variability

Temperatures in the Norwegian Sea follow the so-called Atlantic Multidecadal Oscillation (AMO). This 60-year climate cycle bottomed in the early 1970s, peaked around 2007 and is expected to be negative over the next 20 years from now.

Climate change
Climate change will probably lead to higher temperatures at the peaks and troughs of the coming cycles, but I expect the about 60 years AMO cycling to continue as for instance documented in sedimentation layers on the seabed since the last ice age of 10,000 years ago.

So, during a period of continuous decline of salmon stocks from in particular the southern European area from around 1973, temperatures in these main feeding areas for European postsmolts have been rising and peaked in 2007 and have dropped to around normal today.

Consequently, there is no correlation with temperatures and the collapse of the southern European salmon stocks but there is a very good correlation with the growing mackerel stock and its potential for competition with and predation on the European postsmolt salmon.

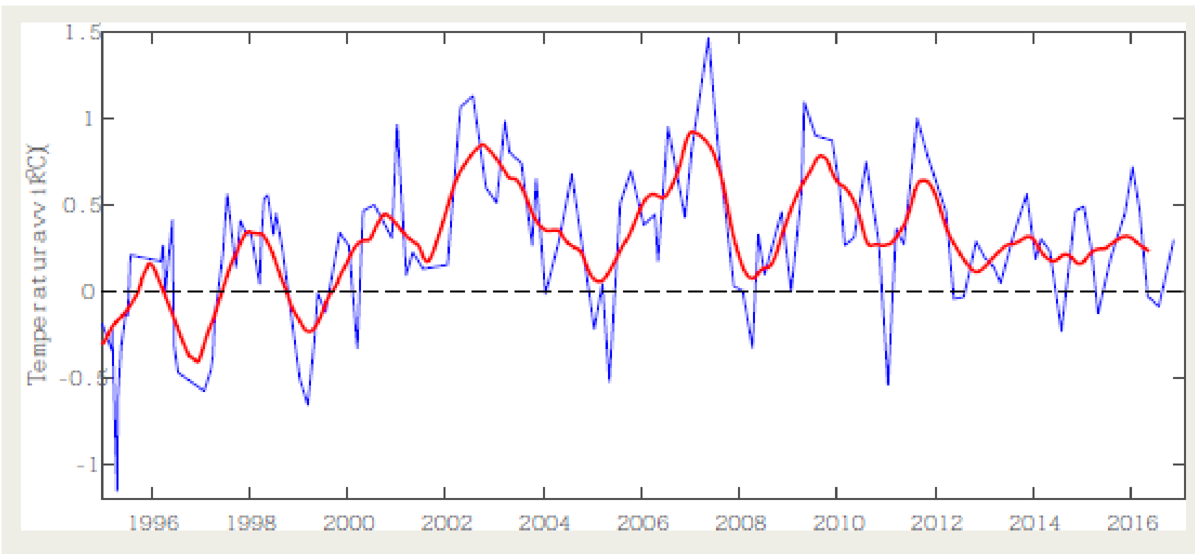


Figure 12. From the Institute of Marine Research report 2017: 'The Norwegian Sea: The temperatures in the Atlantic water along the Norwegian continental shelf have since 2013 been close to or slightly above normal. The temperatures in 2016 were mainly above normal, except the south-eastern Norwegian Sea were the temperatures were lower than normal.'

An international thinning fishery for mackerel
Despite the AMO having turned negative more than 10 years ago European salmon stocks continue their negative spiral and fishing has almost ceased as the stocks are close to or under conservation limits in particular in the southern NEAC area.

In my view, this situation will probably continue to worsen until the heavy competition and predation from mackerel is reduced. The reduction should in my view be done through an internationally agreed and closely monitored thinning fishery on mackerel, where some of the extra catch goes into reduction to meal and oil.

Not to give the pelagic fishermen higher quotas but to bring the ecosystem of the Norwegian Sea and neighbouring seas back within 'normal' ranges where both salmon and seabirds dependent on plankton and small fishes will return to sustainable stock levels.

Is it risky to actively reduce the mackerel stock?
It is claimed that such a thinning fishery will be too risky. I do not agree in this view. By closely following some primary indicators directly linked with the mackerel stock on a running basis one will be able to evaluate almost instantly the effect of a lowered mackerel stock and the lowered grazing pressure from it. Such primary indicators will be the individual growth of the mackerel, the size of the mackerel distribution area and the concentrations of the main food of the mackerel in the Norwegian Sea, the copepod *Calanus finmarchicus*. Once the stock becomes closer to or within sustainable levels the thinning fishery would be reduced and eventually stopped.

Somewhat delayed one will also start seeing positive changes in more secondary indicators, like for instance in stock levels of amphipods, sprats and sand eel, kittiwake breeding success, recruitment in the Norwegian spring spawning herring and postsmolt salmon growth and survival. One good secondary indicator will be the ratio of grilse over multi sea winter salmon in salmon stocks, which will start increasing quickly from today's record low levels as soon as the food availability for postsmolt salmon improves as a result of lowered competition from mackerel. Changes in the secondary indicators will be delayed because they are not directly linked with the mackerel stock and because these indicators are more slow growing species, depending on more time to rebuild sustainable stock levels than for instance the short lived *Calanus finmarchicus*.

Salmon bycatch in a mackerel thinning fishery?
Another worry is the possible bycatch of salmon such a thinning fishery for mackerel could cause. Based on the present knowledge about the seasonal overlap between different salmon ages and mackerel it will in my view be possible to advice areas and periods for such a thinning fishery that would minimize bycatch of salmon and other fishes. If some bycatch of salmon should occur it will in any case be worthwhile due to the large potential of increased salmon stocks that the mackerel stock thinning fishery would lead to.

Looking at figure 9 I will grossly estimate a 'normal range' for the southern NEAC salmon catch to be in the range of 2000-3000 tonnes while the corresponding northern catch would be 1500-2000 tonnes. In my view the early 1970ies salmon catches were over the 'normal range' due to the late 1960ies herring and mackerel collapse. Both herring and mackerel being out of the Norwegian Sea ecosystem during the early 1970'ies led to an 'un-natural' situation with extremely high food levels and potential low predation levels from mackerel for the European postsmolts.

Conclusions part 1

The hypothesis on overgrazing and predation has been hard to sell within the ICES community, in management bodies, with politicians and with the wild salmon lobby. The reason for this is that the hypothesis challenges one of the cores of ICES activities, the accuracy of pelagic stock estimation. It also challenges the hypotheses that sea lice and escaped farmed salmon are the most serious threats for the wild salmon today. Nevertheless, in search of getting our salmon, sea birds and high quality mackerel for the markets back, every obvious stone must be turned.

I have worked with a wide range of mortality factors on wild salmon at sea since 1991, including sea lice, disease and bycatch. It is my strong recommendation that also this hypothesis should be treated and tested seriously. The empiric basis is very much larger than can be shown in this handout.

The ocean is something large and unknown for most of the salmon, sea bird and mackerel trade communities. I think this is the main reason why for example most discussions on understanding and managing the wild salmon focus around rivers and near shore issues. The time is overdue to look out at sea through an ecosystembased perspective. I will guarantee an interesting and intriguing journey that will give you an entirely new view on why the salmon and sea birds vary in numbers and why they are not as numerous as they used to be. And why the G6 mackerel is gone and the remaining mackerel of poor quality today. Let’s start today and bring back all of them, like they used to be and like they should be in a sustainably managed ecosystem!

So I ask: What is most likely to kill a northward bound 15 cm Corrib postsmolt salmon today — temperatures close to normal or a starving mackerel?

Chapter 2

Why is the 2018 ICES assessement and quota advice on NE Atlantic mackerel a gross underestimate?

The mackerel explosion which never turned up in the mackerel quotas

In an article in the Norwegian popular science magazine "Naturen" No. 6/2016, (https://www.idunn.no/natur?languageId=2#about) the stock responsible scientist on mackerel at the Institute of Marine Research, Norway (IMR), Leif Nøttestad and management scientist Kjell Rong Utne at IMR writes: "*The mackerel stock has undergone an incredible growth in the amount, extent and density over the past ten years. It has been documented how the mackerel has gradually spread northward in the Norwegian Sea and into neighbouring sea and coastal areas. The mackerel stock is now distributed within many countries' economic zones - Norway, the EU, the Faroe Islands, Iceland and Greenland, as well as international waters. Since the mid-2000s, the spawning biomass of mackerel has risen sharply. During the same period, the mackerel has increased the distribution during the feeding period in the summer from 1 million square kilometers to over three million square kilometers, and had a doubling of density from 1.5 to 3 tonnes / km2. The main reason for the formidable increase in the distribution of mackerel over the last decade is assumed to be the sharp increase in stock size. There has been historically strong recruitment over the past ten years, including five of the strongest year classes ever recorded. A large mackerel stock needs much more space than a small mackerel stock. In addition, there is great competition for limited food resources, which causes the mackerel to migrate further north and west in the summer in search of food.*" (Figure 5).

Since this article was written in 2016 the ICES International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in the Norwegian Sea and adjacent seas measured the largest spawning biomass index ever at 10.3 million tonnes of mackerel. Accordingly, the amount of mackerel today must be considered as larger than what the article describes. As mentioned earlier another result of the stock 'explosion', the mackerel has expanded its spawning areas from mainly west of the British Isles and the North Sea to large parts of the Norwegian Sea from the Faroe Islands and across to the Norwegian coast to the northernmost part of Norway (Figure 3, 4 and 7). In 2014, 2016 and 2017, the recruitment of mackerel seems to have been successful in these areas, and today large parts of the Norwegian Sea and many Norwegian fjords are well-filled with young mackerel (Figure 10). This young mackerel comes in addition to the grown-up mackerel also grazing and spawning in these northern areas. The mackerel's expansion in the north-east Atlantic was in no way complete when Nøttestad and Utne wrote their article in 2016. The growth has continued and we have probably not have seen the most serious consequences of it yet.

In summary, according to the IMR, the mackerel distribution is currently over three times as large as ten years ago, and the density has doubled. Accordingly, based on the record measurement from the IESSNS survey in 2017, there must be at least six times more mackerel in the NE Atlantic today than in 2007. With at least a sixfold increase in stock size over the past ten years in mind, the question mark arises when we read the ICES 2018 Mackerel Advice, the "ICES Advisory Sheet 2017". In the advice we can see that ICES estimates that the spawning stock in 2008 was 2.8 million tonnes (Figure 13). In the quota advice for 2018, ICES estimates the mackerel spawning stock to be 3.1 million tonnes in 2018, an increase of approx. 10 percent from 2008. In view of Nøttestad and Utne, claiming that the stock has increased by a sixfold it is not understandable how the spawning stock estimate and quota advice has only risen by 10 percent? If we multiply the estimated spawning stock in 2008 of 2.8 million tonnes with six, as indicated by the trawl survey, we will get a spawning stock in 2018 of 16.8 million tonnes. This is a spawning stock significantly more in line with what the fishermen experience at sea and the reality in the ocean in my view.

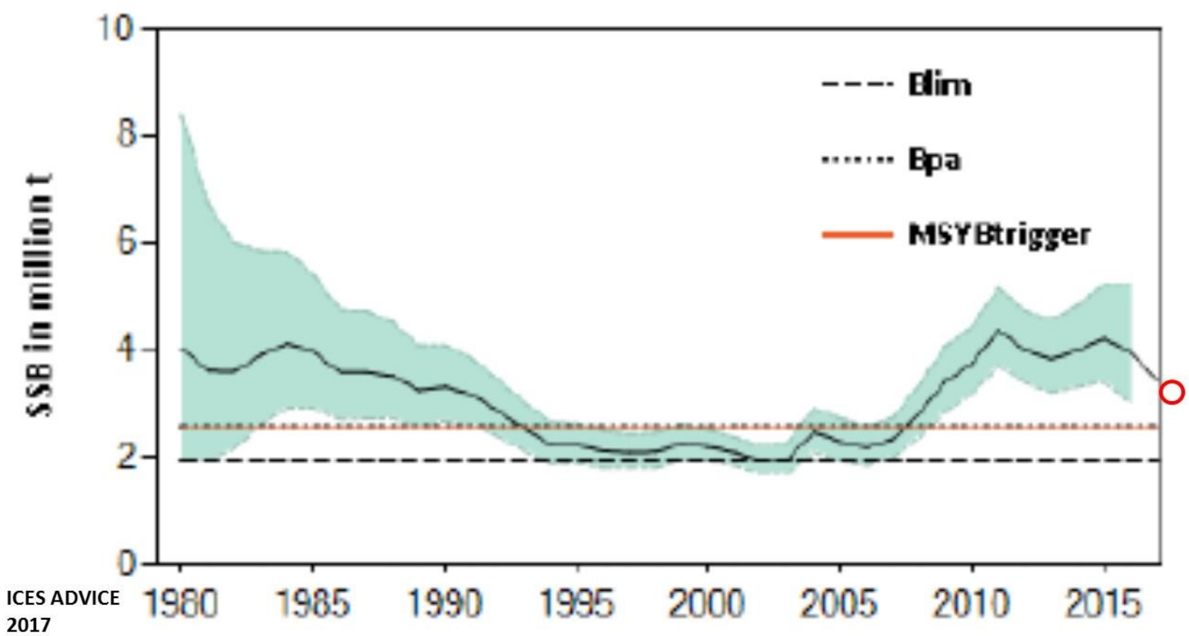


Figure 13. Spawning stock development of the NE Atlantic mackerel stock. The red circle is the spawning stock size for 2018 as projected by ICES. Inserted by the author. From ICES ADVICE 2017.

Furthermore, in 2008, the spawning stock was in my view probably largher than 2.8 million tonnes, a view supported by calculations made by scientists at the IMR which we will look into further down.

So how did we end up in a situation where all scientists, sports- and professional fishermen observe that the ocean is filling up with more and more mackerel, while the stock estimate and quota advice of ICES remain close to constant?

Mackerel stock estimation and stock assessment

Today three methods are used to estimate three independent spawning stock indexes of mackerel: the egg method, the trawl method and the tag method. All three stock indexes are included in the stock assessment of the NE Atlantic mackerel stock from the 2017 advice. I will first present a very brief overview of the three methods, then I will evaluate how the spawning stock biomass index coming out of each of the three methods are used and handled in the mackerel assessement today.

The three methods can be explained very simplified as follows:

<u>Egg method:</u> By hauling a plankton net through the water at many different positions supposed to cover the entire mackerel spawning period and spawning area, it is estimated how many eggs the mackerel stock have spawned in a certain year. This number is used to estimate how many female fishes are required to produce these eggs, and then this number is multiplied by two to account for the males. Then this number is multiplied by the estimated average weight of all spawners which gives a biomass index for the spawning stock of mackerel.

Triannual egg surveys started west of the British Isles in 1992 and the last survey in this area was in 2016. There is also been a parallel egg survey in the North Sea.

<u>The trawl method:</u> It is systematically trawled with the same trawl and trawling method over an oceanic area that is supposed to contain the entire spawning stock of mackerel in the summer. The catches in the individual hauls are distributed on the trawled area, and the average density of mackerel per square kilometre is calculated. Then this density is multiplied with the size of the entire area covered by the survey which gives an index for the total spawning stock biomass.

<u>The tagging method:</u> Mackerel is tagged in spring west of the British Isles. Based on the numbers of fishes tagged, knowledge about the tagging mortality, detection of tagged fish in commercial catches and the size of these catches it is possible to estimate the size of the mackerel spawning stock.

Mackerel has been tagged for migration studies and stock assessement purposes yearly west of Ireland and Scotland in May starting in 1969. There are two tagging series on mackerel now used in the ICES stock assessment. The first series was started in 1969 using magnetic steel tags. It ran up to 2007 when the series was ceased amongst other because of problems with collecting tags efficiently from the fish plants. A new series was started in 2011 using so called electronic RFID tags. In the steel tag experiment from 5600 to 34000 mackerel were tagged annually. Between 2011 and 2017 on average 52.260 mackerel have been tagged electronically per year. The steel tag series is only used for the years 1980-2005 in the 2017 assessement and electronic tag recaptures from 2012 to 2016.

The electronic tags are detected automatically when a tagged mackerel passes through an electric field mounted around the delivery bands at 17 fish plants in Denmark, Faroes, Iceland Ireland, Norway and Scotland. When the tag inside a mackerel passes through the electric field, a voltage builds up in a copper coil inside the tag. This voltage makes the electronics in the mark transmit a unique identification code. The code is detected in the electric field and are sent continuously to the IMR tag database via the net. In addition to the tag identifiers, it is important for the IMR to receive reliable information about the amount of mackerel that passes through the tag detectors at the various plants.

Evaluation of the use of the three stock biomass indexes in the stock assessement

The egg method:

The spawning stock biomass index which came out of the egg investigations for western mackerel in 2016 was 3.8 million tonnes. I will argue that the egg method produces a spawning stock index that systematically underestimate the biomass of spawning mackerel. One obvious explanation to this is that the survey only covers the area from Portugal to the west of the British Isles north to between Shetland and the Faroe Islands (Figure 4). Thus, the egg production is lost over a large sea area in the Norwegian Sea and along the Norwegian coast, and thus a lot of the spawning stock in the spawning stock biomass index (Figure 7).

In the 2016 executive summary of the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys it is stated: *"However, analyses showed that the mackerel core spawning area was covered and a reliable estimate of mackerel annual egg production was delivered."* Given the available knowledge that mackerel has spawned in the Norwegian Sea since 2008 (Figure 7) it is not understandable how the ICES working group can claim they have worked up a reliable estimate of the annual egg production of the mackerel stock in 2016.

In the Norwegian fisheries paper 'Fiskeribladet' of 26th May 2016, the head of the pelagic section at IMR, Aril Slotte, states in an interview that *"We are looking into expelling the 2016 egg survey results for mackerel as it appears that not the whole spawning stock was covered".* Obviously the ICES scientists are aware of this serious bias in the egg survey and are willing to start omitting the egg data from the assessement. This opens a totally new view on the mackerel assessment where the IESSNS survey and the tags will play a much more important role.

Apart from the area and periods not covered by the survey there is something more and inexplicable in the egg method that strongly underestimate and smooth out the stock variations that are obviously occurring in the spawning stock of mackerel (Black squares in figure 14). In my view, this can be due to density-dependent spawning over time, horizontally and vertically. That is, the mackerel regulates the spawning density in a way we are unable to capture in the estimation of egg production. In this way, we lose more and more eggs both horizontally, vertically and temporally as the stock increases and needs more time, area and depth to carry out the spawning with about the same density of fish. Another possible explanation can be strong predation on the eggs that is not taken account of in the estimation of egg production. There may also be other reasons to the underestimation of the egg production.

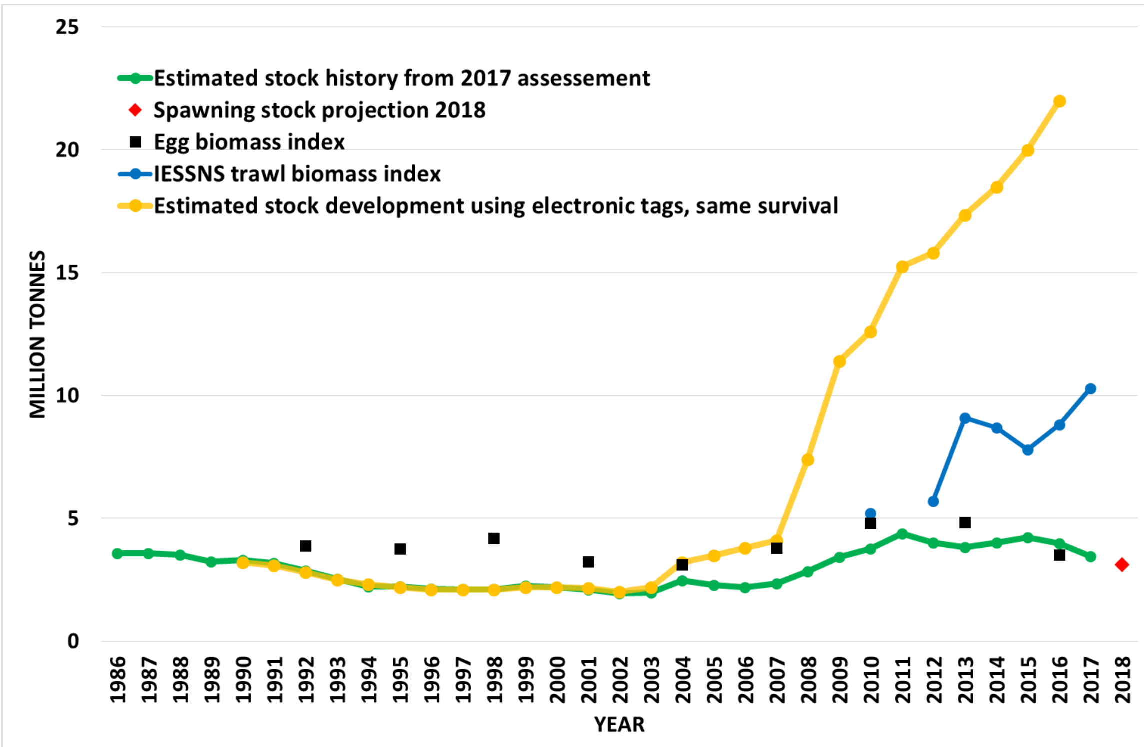


Figure 14. The figure shows various stock indexes and estimates on the NE Atlantic mackerel produced by ICES. The green line is the spawning stock size history as estimated and presented by ICES in the 2017 stock advice. The red diamond is the 2018 spawning stock projection for 2018 taken from the 2017 ICES stock advice. The black squares is the spawning stock biomass index coming out of the triannual western egg survey starting in 1992 as presented by ICES WGWIDE in 2018. The blue line is the biomass index coming out of the IESSNS trawl survey as presented by ICES WGWIDE 2017. The yellow line is the spawning stock development coming out of the tag experiments when equal tagging mortality is estimated for the steel and electronic tags. The first part of this dataseries is from figure 16 in this document. The latter part, after the curve goes outside the y-axis of the graph is reconstructed using the F values in the right panel of figure 16.

It is well documented that the mackerel quota was heavily overfished for many years by different nations without the stock collapsing. During this period the egg survey was the only spawning stock biomass index. This further strengthens the view that the egg method has systematically underestimated the mackerel stock for many years.

The trawl method

The scientists who participated in the ICES Mackerel Benchmark in 2017, did not appreciate the high estimates emerging from the IESSNS surveys. The high numbers simply do not fit into the assessement model.

In the general discussion of the results of last year's trawl record, the scientists write on page 9 in ICES WKWIDE 2017: *«The estimates in absolute terms are likely to be biased (upwards, potentially by a factor of 2) due to the use of wing swept area in the estimation of fish density. Mackerel are likely to be herded by the boat, the doors, and the net, and although an appropriate factor may be difficult to determine, the use of door spread, which represents the larger area sampled would provide a more conservative estimate. This point is all the more compelling, given that the catchability of the survey from the assessment is 2, and the wing spread is half the door spread (i.e. if door spread was used, the survey estimate would be half of what it is, and the catchability would be 1).”*

So because the stock estimate from the trawl survey is larger than the scientists had anticipated, given the prior view on the stock size based on the egg survey, the scientists explain the large biomass index from the trawl survey with the trawl probably catching twice as much mackerel as what was in the water mass sifted through the meshes of the trawl. This means that they are of the opinion that the vessel, the doors and the sweeps collect the mackerel in front of the trawl itself. But this view is ‘taken out of the air’ when suddenly the trawl survey give a large result conflicting with their prior much lower view on the spawning stock based on the egg survey.

It is consequently a very critical point how large the effective catching width of a trawl is (Figure 15). In my view the efficient catch width of the trawl should be determined by independent methods, not as a result of a survey result which is ‘found to be too large’ given the results coming out of the egg data series (Figure 14).

The assumption is that the IESSNS trawl survey overestimates the spawning stock by a factor of two is in sharp contrast with the assessments of former foreign and Norwegian skippers on the IESSNS survey. (Today's Norwegian skippers have signed a confidentiality declaration). According to these, very much of the mackerel disappear below the trawl and is not caught. Much of the mackerel in an area therefore does not appear in the trawl catches and subsequently not in the trawl survey spawning stock biomass index.

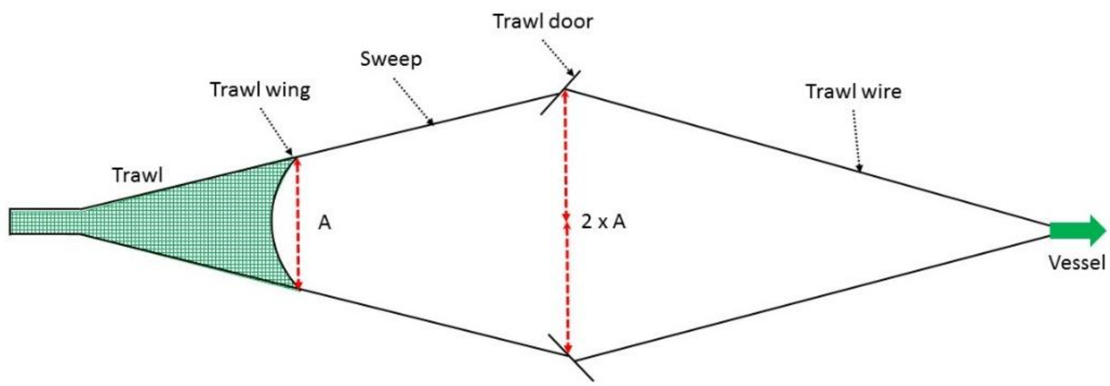


Figure 15. What parts of a trawl are actually collecting the mackerel and how wide area does a pelagic trawl catch mackerel from? This number is critical to the biomass index coming out of the IESSNS trawl survey. When the ICES WKWIDE scientists get a biomass index from the IESSNS trawl survey that is too large in their opinion, they choose to use the trawl door distance (2xA in this figure) to calculate the density of mackerel in the ocean instead of the trawl wing distance (A in this figure). This halves the density of mackerel in the ocean and halves the biomass index. No pelagic trawl skipper would agree that all the mackerel passing between the trawl doors would end up in the trawl cod-end.

They are also of the opinion that the semi-circular trawl method, the so-called 'banana haul', used in the survey is destroying the trawl's normal symmetry and fishing efficiency. They claim that by trawling in a semi-circle less fish is caught than when trawling the same volume of water straight ahead. No commercial fishing boats living from their catch would trawl in a circle the way the research vessels do in this survey. In one case, a survey vessel was allowed to trawl straight ahead in the same area as it had trawled in semi-circle just before. These two straight hauls each gave about a double catch compared to the banana haul.

On my own account I would like to add:
a) No corrections are made for the mackerel trying to swim out off and along inside with the trawl during the capture phase. Even though the trawl is hauled at five knots, ie approx. 2.5 meters per second, the mackerel will keep up with the trawl for a while before it is exhausted and ends up in the cod end. Much of the mackerel inside the trawl belly when the vessel stop towing and start hauling the trawl will consequently swim out of the trawl as the speed of the trawl is strongly reduced at that stage. Summing up, the trawl does not capture all the mackerel that was in the water mass sifted by the trawl meshes before the start of the haul. To compensate for the swimming of the mackerel during the haul and those swimming out when the towing stops, the catch should be multiplied up by a factor greater than 1. This is not done.

b) There are large areas of mackerel that are not covered by the trawl survey. This applies to the North Sea, the Norwegian fjords, Skagerrak, Kattegat, the Danish belts and the areas around the

British Isles (Figure 6). Reports from various sources throughout this area tells that there are large amounts of mackerel also in these areas not covered by the IESSNS trawl survey.

Based on the factors above it is my opinion that the spawning stock biomass index from the trawl survey in 2017 at 10.3 million tons is a large underestimate of the real spawning stock size. The ICES scientists, however, decides based on feelings that the trawl survey overestimates the spawning stock by a factor of two. Therefore it is decided to double the efficient trawl width from between the wings to between the doors which halves the spawning stock biomass index coming out of the trawl survey.

The tagging method

In the case of stock estimation with tags, the tagging mortality is a fundamental size. "Tagging mortality" means the additional mortality the actual tagging process causes the mackerel. Important causes may be mortality due to so-called osmotic leakage, another cause bleeding and a third that the tagged mackerel is eaten by predators after it has been released from the vessel.

Osmotic leakage means that freshwater flows through the skin where the mackerel has lost scales during tagging. If this leak grows larger than the amount of freshwater the gills can pump into the fish, it will slowly, but surely get saltier and saltier inside, dry out and eventually die. If the loss of scales is at the limit of what the fish can withstand, this process will occur within days after the tag was inserted. If the scale loss is large, it will die quickly. When tagging herring and salmon it is easy to see how much scales a fish has lost, thus avoiding tagging individuals who have excessive scale loss. For mackerel, it is harder to see this, so that the handling and assessment of individuals becomes even more important. The tagging process on the IMR tagging surveys is led by highly experienced and skilled personnel, who do what they can to make the tagging process as gentle as possible. Among other things, the individual mackerel is considered carefully before tagging and bleeding mackerel is not tagged. Earlier, the tagged fish were released on the lee side of the vessel, ie up against the wind. This gave the gannets good conditions to hang over the area the mackerel was released into, then to dive down and eat the tagged mackerel.

In connection with a new tagging procedure introduced in 2006 the fish is now released downside the wind. The mackerel is also released through a hose running under the gannet diving depth. These changes makes it almost impossible for the gannets to eat the tagged fish. Therefore, the mortality rate due to predation from the gannets must be considered to be significantly less today than before the new procedure was introduced.

The pensioned skipper Lodve Gjendemsjø on the Norwegian purse seiner "Inger Hildur" who has participated in 17 herring and 3 mackerel tagging surveys for the IMR told me "*I participated in tagging surveys using both the old and the new tagging procedure on mackerel. I consider the new one to be much better than the old one and the tagging mortality must have come down a lot.*" He listed the following reasons for his view: a less intrusive handling of the mackerel, round keep tanks instead of rectangular ones allowing the mackerel to swim in circles rather than swimming into the corners of the tank and less predation by gannets du to release of the mackerel downside the wind and through a hose.

Tagging data in the mackerel stock assessment

During the ICES Mackerel benchmark in February 2017, the ICES stock assessement model SAM was adapted to include the two tag data series. Several runs were made with different settings. Amongst other, a run where the model used equal tag mortality for the two tag series. This resulted in a stock estimate so high that the number was outside the Y-axis of the standard graph used in the report. In Figure 16 this is the light blue line that "disappears through the roof". About this run the benchmark scientists say in the WKWIDE report on page 41: «*The model assuming a single survival rate and overdispersion was clearly not appropriate, estimating unrealistic SSB (spawning stock biomass) and Fbar values (Figure 3.3.4.1). The post-release survival rate estimate, mostly representative of the steel tags which represent the bulk of the data, appears to be too high for the RFID tags and the model can only deal with the lower recaptured numbers in this dataset by estimating large stock-abundance for the corresponding cohorts.* » The stock estimate for 2016, which is not shown in the graph because the Y axis is too short, can be estimated to be around 22 million tonnes (Yellow line in figure 14). This figure was considered to be too high by the scientists which describes the estimate as "clearly not applicable, estimating unrealistic SSB and Fbar values".

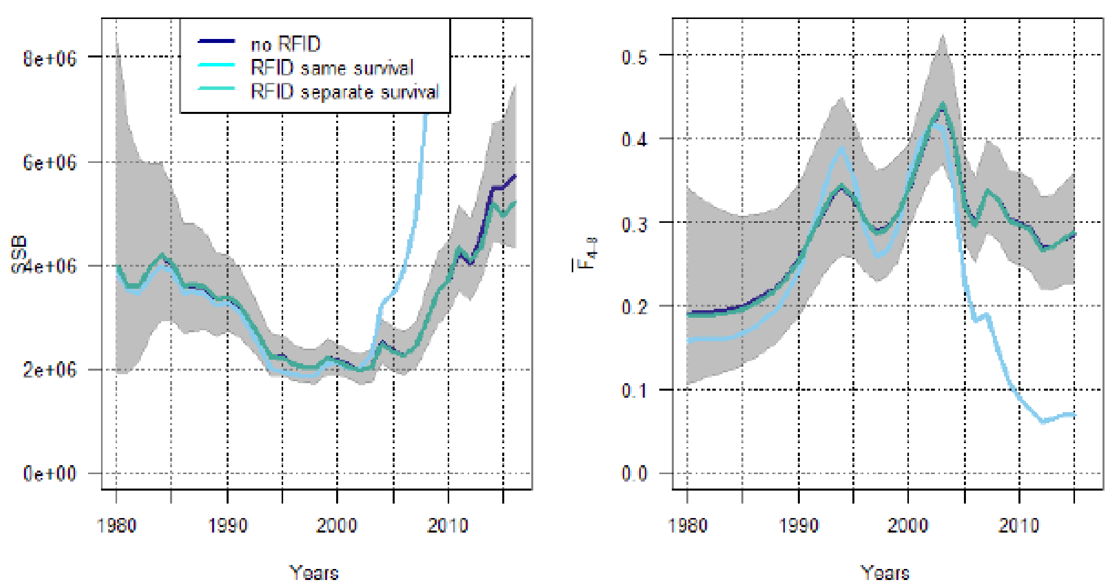


Figure 16. When the WKWIDE benchmark scientists made a model run assuming equal tag mortality for the old steel tag series and the new electronic tags the estimated spawning stock passed up ‘through the roof’ of the standard graph, light blue line in the figure. At the same time the fishing mortality, F, in the right graph dropped down to 0.07. The scientists did not like this high stock estimate and rejected it as ’unrealistic’.

Again the scientists reject a result emerging from the observational data based on feelings. As the model run assuming equal tag mortality between the old and new tag series gave a "*clearly not appropriate, estimating unrealistic SSB"* they decided to overlook the result and run the model with unequal tag mortalities which heavily takes down the estimated spawning stock from the electronic tags, to level it with the egg biomass index.

The scientists then ran the model so that it should estimate separate tagging mortality for the steel tags and the electronic tags. In order for the equation to "go up", the model came out with a tagging mortality at 61 percent for the steel tags and 92 percent for the electronic tags. This means that the scientists accepted that 92 out of 100 mackerel tagged with electronic tags dies as a result of the tagging. And the explanation? This gave a much smaller stock estimate which they considered acceptable.

Then, in the WGWIDE 2017 working group, the scientists accepted an estimated tagging mortality of 91 per cent after the same principles as described in WKWIDE 2017 above. However, in an interview in Norsk Fiskerinæring, May 2018, the head of the mackerel tagging project and leader of the pelagic section at IMR Aril Slotte says "*The estimated tagging mortality of over 90 percent is not understandable in my eyes. It is also difficult to understand for our tagging staff who assess the quality of mackerel before tagging. Consequently, I assume that the tagging mortality is not as big as 90 percent. But to assume does not hold. We must document with scientific methods and data.*" The latter sounds very reasonable to me. However, when it comes to rejecting equal tagging mortality between the two tag series, it is enough to assume that they must be different to reject the high result. Although the staff, who have long experience in sorting the mackerel before it is tagged, say that they use exactly the same criteria to sort the mackerel as before.

How high is the real tagging mortality?

Two experiments on tagging mortality in mackerel has been carried out. One by Hamre (Hamre, 1970) and one by Lockwood (Lockwood et al., 1983). In Hamre's experiment 100 internally tagged mackerel and an untagged control group of 100 were kept in a keep net together for three weeks. The mortality rate of the tagged mackerel was 18% and the control group mortality was 9%. In Lockwood's experiment 93 tagged and 92 untagged mackerel were kept in a keep net for 15 days. The mortality of the tagged group was 18.3 % and control group survival was 4.3%. There were not predators around in these experiments but one could for instance think of negative 'laboratory' effects on the survival rate related to the keeping of the mackerel in net pens for up to three weeks in both these experiments. Such effects would not apply to the 'at sea tagging' where the mackerel is back at sea within very short time after being fished and tagged.

An article by Tenningen, Slotte and Skagen from 2010 (Tenningen et al., 2010) deals with testing the tagging method for mackerel in stock estimates based on the old steel tags. Compared to how benchmark and WGWIDE 2017 treat the tagging results, the conclusion in the paper is remarkable: «*The spawning stock biomass estimates derived from two different tag-based* *models were highly variable, but were on average 2 and 2.3 times higher than the ICES official estimate. The official estimate is considered uncertain and most likely to underestimate the actual biomass due to unregistered fishing mortality and lack of fishing-independent, age-disaggregated data. Hence, tag-based estimates could potentially improve the current assessment if included in the ICES stock assessment on a regular basis. These estimates also involve some uncertainty that needs assessment, especially related to variable tagging mortality, detector efficiency and migration of the stock.*» In this article, tagging mortalities at 30, 40 and 50 percent were used, which is very far below what the scientists accepted in the mackerel advice for 2018 at 91%.

When the ICES scientists in WKWIDE and WGWIDE accepts a tagging mortality at up to 92% to get the model equations 'to go up' with the catch and egg data it is simple and plain manipulation with data and not science in my view. It is simply a totally unacceptable way of working for ICES.

So, in general when the ICES scientists get a stock biomass estimate from the IESSNS trawl survey or the tagging experiments that doesn't fit into their prior perception of the stock, they simply do some massaging of the data series and come up with lower spawning stock indexes that fits better with their prior perception of the stock size. This prior perception is mostly based on results coming out of the egg data series, a series they admit underestimates the spawning stock and which they are ready to partly exclude from the assessment according to Aril Slotte. Again, this is not a scientifically acceptable way of working within ICES in my view.

How large is the mackerel stock today?

As we recall from the chapter on the mackerel explosion that disappeared, the observations from the trawl survey indicate at least a sixfold increase in the mackerel stock from 2008 to 2018, from 2.8 to 16.8 million tonnes. 16.8 million tonnes is not far from 22 million tonnes, as the tagging series indicate using equal tagging mortality the steel and electronic tags. Again, based on all available information, I will strongly claim that at 22 million tonnes we are significantly closer to the actual size of the mackerel stock than the 3.1 million tonnes ICES estimated for 2018 (Figure 14).

If we assume that the tagging mortality of the two tagging methods is actually about the same and that the run of WKWIDE 2017 is both 'appropriate' and 'realistic', we will get a stock development that starts to increase sharply from approximately 2003 and which reaches somewhere above 20 million tonnes in 2018. Such a development will suit the development described by Nøttestad and Utne based on the increase in distribution and density of the stock as indicated in the IESSNS trawl survey (Figure 5). With such a solution to the equations, the map begins to fall in place relative to the terrain.

The whole story becomes even more incomprehensible and less consistent if we look at the tag-based stock estimates in Tenningen and others (2010). In this paper it is estimated that the mackerel stock based on the steel tags was just over 7 million tonnes in 2005 and 2006 (Figure 17). If this is our starting point at that time and we multiply with 6, we end up with an estimate of the mackerel stock of around 40 million tonnes in 2018. This biomass is well in line with what an experienced skipper who has participated in the trawl surveys previously claimed in a conversation: "After what I've observed and experienced in the mackerel surveys, the mackerel stock can well be between 40 and 50 million tonnes."

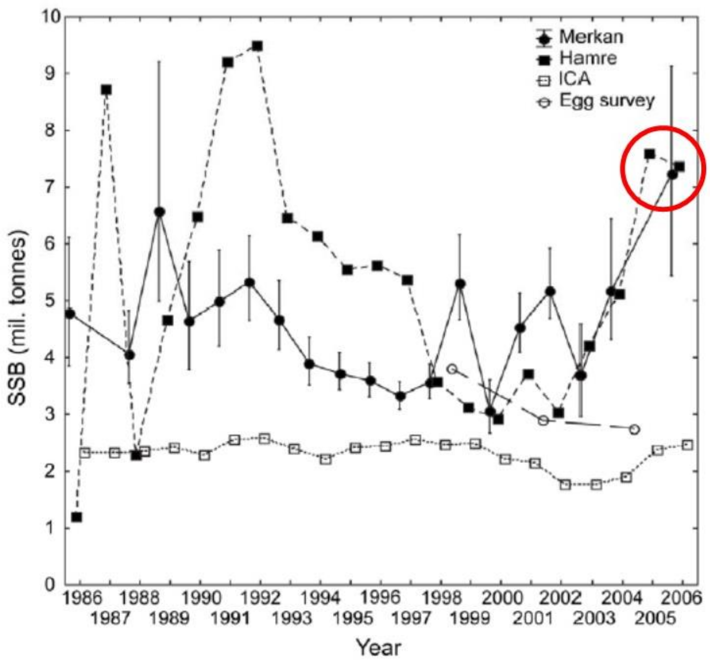


Figure 17. Stock estimates of 3-12 years old mackerel, 1986-2006, based on the MERKAN and HAMRE tagging models. The estimates are compared with the official stock estimates (ICES, 2009) and the triannual egg survey (ICES, 2008). The estimates circled in red are at about 7 million tonnes are the MERKAN og HAMRE estimates for 2005 og 2006 as mentioned in the text above. From Tenningen et. al. 2010.

Summary about the mackerel assessment

Today we have three biomass indexes of the mackerel stock, all of which all indicate a mackerel stock significantly larger than the ICES forecast for the 2018 spawning stock at 3,1 million tonnes (Figure 18). The egg data indicates a stock of 3.8 million tonnes, the trawl survey a stock at 10.3 million tons and the tagging data a stock around 22 million tons given equal tagging mortality. But the ICES scientists have no doubt that the spawning stock index at 22 million tonnes emerging from the tagging experiments is too high and that the 10.3 million tonnes trawl index overestimates the stock by a factor of 2.

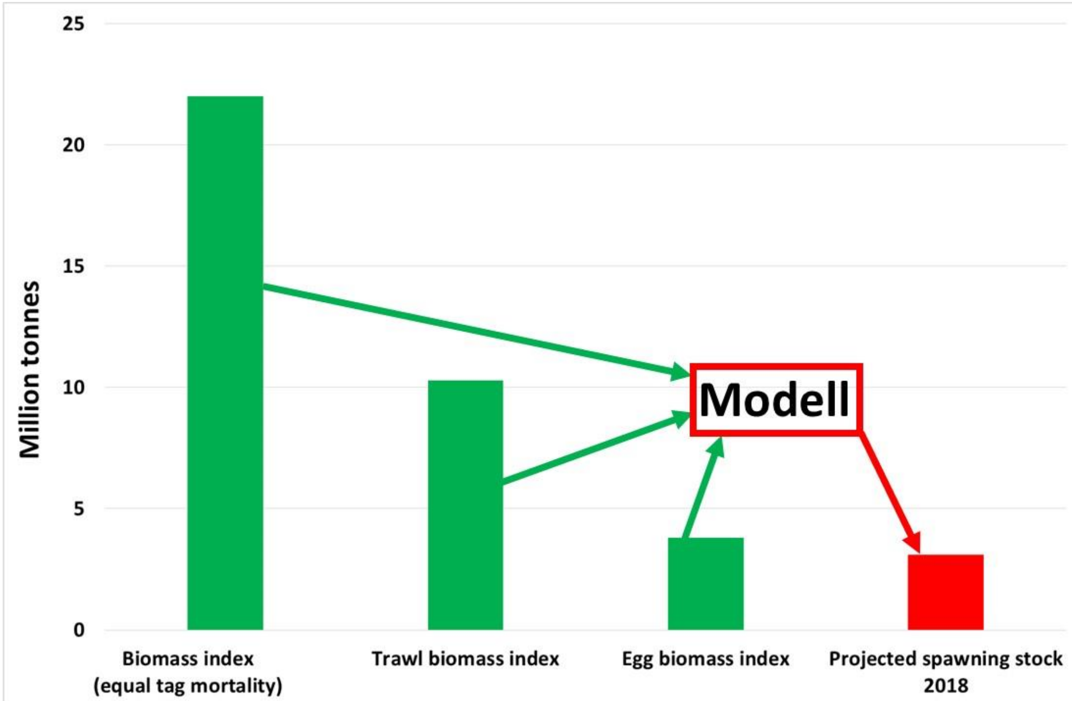


Figure 18. Starting out with three spawning stock biomass indexes at 22, 10,3 og 3,8 million tonnes the ICES WGWIDE stock assessment ends up with a stock assessment at 3.1 million tonnes. In addition to the three spawning stock biomass indexes the assessement model uses catch data and a recruitment index as input.

How, then, can the model come out with a stock estimate that is even significantly less than all the three spawning stock biomasses? In addition to the fact that the scientists reduce the size of the indexes they find 'too large', the assessment model is programmed to weigh the biomass indexes inversely relative to the size of the standard deviation (variation) to the individual data series. This means that little variation in a data series gives high weighting, large variation gives low weight. Because the catch data and egg biomass index have low variations, these data sets get high weights in the model result while the trawl survey and the tags have high standard deviation (high overdispersion for the tags), and consequently gets low weight and little significance for the model result. This weighting is done without at all discussing how accurate the different series are; that is, how well they hit the real spawning stock size in the ocean. And no independent investigations are carried out to try to find out about this

Thus, in the process of approving the size of the various stock biomass indexes used in the model, the rules vary according to what the scientists find an acceptable size. If an index is found too large, given the existing view of the stock, it is adjusted down to fit better. Then the statistics in the model take over and determine what weight a series should have: Low standard deviation, high weight. High standard deviation, low weight. However, the extent to which the individual biomass index hits in relation to mackerel in the ocean is not discussed and does not affect the size of the assessement or quota advice of ICES.

So what accuracy does the final quota advice has in relation to the real stock of mackerel at sea? In my view absolutely nobody know this today. The only thing that is certain based on the above is that the 2017 stock assessement of ICES is far too low.

What went wrong in ICES?

Looking back at the ICES stock assessement and advisory story on mackerel we see that the egg investigations has been the cornerstone, starting in 1992. With its long history it forms the basis for the present general view on the mackerel spawning stock size with the ICES scientists (Figure 14). Then the IESSNS trawl survey was initiated in 2007 and came up with a new and higher stock biomass index. After that the new electronic tagging series was initiated in 2011 and was included in the assessement from 2017, with an even higher spawning stock biomass index given equal tagging mortality between the old and new tagging procedure.

The egg investigations always showed a very stable and low stock (Figure 14). Despite proven heavy overfishing for many years by different nations the stock never collapsed, indicating that the stock estimates based on the tags always was an underestimate. Now, when two new biomass indexes indicate a much higher stock level this come in conflict with the former stock size history estimated from the tags (Figure 14). It is in this situation the ICES scientists fail in my view. Rather than initiating investigations to check the accuracy of the results emerging from the trawl and tagging methods they decide to reduce the indexes based on feelings and further down weigh them in the model using statistically based weighting.

In my view the correct scientific way to deal with this situation would be to initiate independent investigations in particular on the efficient catching width of the trawl method applied in the IESSNS survey and on the actual size of the tagging mortality both using the old and the new tagging procedure. It will be fairly simple to design and carry out experiments which would give a better insight into both the efficient vertical and horizontal sampling width of the trawl, and to the tagging mortality of the tagging experiments. Of course, none of these two sizes will have constant values but well designed experiments will definitely make it possible to get a realistic grip on their real range.

The unfortunate respect for the model results

As I see it, we have had a very unfortunate development where management advice in this field get more and more distant from what the various investigations tell about the size of fish stocks. Instead, the scientists trust the model results more and more. This despite the fact that the scientists are aware of weaknesses, sources of error and broken model assumptions behind the results. These motions are poorly communicated and the model results are interpreted as truths by managers, politicians and the public. At the end, model results almost unrooted in reality end up as the basis for socially, economically and ecologically important management measures. This is a very dangerous development. In more and more areas, this practice leads us to an almost purely model-based management that is not based on the results of various investigations and the reality of the marine areas we manage.

Conclusions

I started participating in ICES working groups in the late 1980'ies. Since then I have participated in a series of groups in particular focusing pelagic fish stock assessment and ecosystem related questions. When I go through the 2017 ICES mackerel assessment in detail, I'm shocked about how the scientists treat the two data series indicating a sharp rise in the mackerel stock and how this assessment has been carried out. In my view ICES need to take a big step back and simply reset the entire mackerel advisory process. A very serious situation has arisen which has brought a whole large ecosystem far outside its natural range of variation with grave consequences for all its inhabitants including man as the ultimate predator and manager of the system today.

This is a deep scientific conflict that needs to be treated as such. Not by trying to stigmatise me and the work I'm doing. I have no other agenda than trying to get the hypothesis on overgrazing and predation tested in an objective and neutral way on behalf of the salmon, the sea birds and the G6 mackerel.

About the auhor

Dr Jens Christian Holst worked as a management scientist on pelagic fish at the Institute of Marine Research in Norway. Today he is an independent fisheries advisor and developer. He started working on the marine ecology of Atlantic salmon in 1991 and moved into general ecosystembased management in the early 2000.

Several of his publications and talks on salmon at sea and related ecosystem issues are found by registering and logging into Researchgate.com or searching at Scholar.com. Relevant search words are salmon, laks, herring, sild, mackerel, makrell, Norwegian Sea and Norskehavet.

To stay independent in the controversial field of wild salmon, sea lice, farmed salmon and pelagic fish, he has not taken on projects since 2016 and finances himself today. This handout and all its conclusions is consequently totally his own work and not paid by anyone. He is involved in projects on closed contained fish farming.

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