

Impact case study (REF3)

Institution: University of Strathclyde		
Unit of Assessment: B10 Mathematical Sciences		
Title of case study: Using stock assessment models to ensure sustainable use of international fishery resources		
Period when the underpinning research was undertaken: 2013 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Robin Cook	Role(s) (e.g. job title): Senior Research Fellow	Period(s) employed by submitting HEI: 01/09/2011 - present
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? No		
<p>1. Summary of the impact</p> <p>Mathematical analysis and modelling by Dr Cook at the University of Strathclyde has identified ways to improve the internationally accepted assessment of a shared cod stock to the west of Scotland. This work resulted in a review of the assessment and a consequent change to the estimated exploitation rate of the stock by the International Council for the Exploration of the Sea (ICES). On the basis of this and the related underpinning research, Cook has established international reputation that has led to him making significant contributions in similar activities, including: reviewing fisheries assessments conducted by the National Oceanic and Atmospheric Administration in the USA; being invited to assess the Marine Stewardship Council quality certification standard for fisheries worldwide; and influencing the UK Department for Environment, Food and Rural Affairs (Defra) fisheries policy. Together, these activities are helping fishery managers around the world manage fish stocks more effectively, sustainably and profitably.</p>		
<p>2. Underpinning research</p> <p>Context</p> <p>The widespread and growing global demand for fish products supports a multi-billion-dollar commercial fishing industry. However, there is increasing scientific, political and public awareness of the damage to marine ecosystems caused by overfishing, especially since the widely reported collapse of Canada's Atlantic cod stocks in the early 1990s. In order to balance the demand for fish products with the need to protect marine environments, it is increasingly important that fishery managers have access to accurate assessments of fish stock health so that they can effectively and sustainably manage such stocks. Cook's research aims to provide this through multiple lines of enquiry, as detailed below.</p> <p>Review of Northeast Atlantic fish stocks</p> <p>In 2013, Cook analysed fish stocks in the Northeast Atlantic, where the majority of stocks are subject to the European Union's Common Fisheries Policy (CFP), a set of rules governing fishing fleets with the aim of conserving fish stocks. The analysis demonstrated that most stocks in the region were recovering and that management interventions were showing some success [R1]. This finding challenged the widely held perception that fish stocks in the Northeast Atlantic were in decline and that the CFP had been a failure. A 2019 assessment by Cook of cod stocks in the west of Scotland also suggested that these stocks have experienced a decline in fishing mortality rate and an increase in spawning stock biomass [R2].</p> <p>Development of new methodologies to assess fish stocks</p> <p>In order to accurately assess the effect of fishing on marine ecosystems it is essential that robust assessments can be made of exploited fish stocks. Cook's research has focussed on the development of state-space models that can integrate data from a variety of sources, by accounting for the processes that gave rise to the observations and weighting the data in an objective statistical framework, so that the exploitation status of fish stocks can be monitored. The</p>		

models make use of time series methods and are cast in a Bayesian framework. Particular novel aspects of this research relate to fish discarded at sea and bycatch of less abundant species that are important for biodiversity.

Quantities of discarded fish can be large, accounting for as much as 50% of the catch. However, as discarding occurs at sea it is rarely observed, and discard data are often extremely sparse and unreliable [R3]. Further research by Cook therefore focussed on developing a methodology to account for discards in fish stock assessments [R4]. This was achieved by modelling the size selection of fish by fishers and the effects of quota limits on discard behaviour. Where the available data are very limited to assess stocks, methods were developed which made greater use of research vessel survey data that have been collected for many years but not fully exploited as an information source [R5]. By combining this information with landings data, new models were developed which allow the use of size frequency data to assess population status for stocks. The population model is stage structured (recruits, juveniles, adults etc.) making it possible to use length data as a proxy for age. This allows the assessment of stocks for which the absence of age data had previously prevented assessment and which therefore resulted in little or no advice being available to managers [R5].

Investigating the effect of seal predation on cod stocks

Another important strand of Cook's research has focussed on quantifying the effects of grey seal predation on the west of Scotland cod stock [R6], a previously overlooked area of cod stock assessment. This work required the development of a state-space population dynamics model that included a predation sub-model for seals. The model can make use of periodic observations of seal diet collected by the Sea Mammal Research Unit at St Andrews University to estimate the parameters of a predator functional response and hence estimate the predation mortality. The model can more realistically estimate current fish stock size by taking into account this mortality and can be used to investigate fish stock recovery under different seal population scenarios [R6]. As relevant data is limited, a key element of the modelling is to include time series processes to overcome the problem of missing data. Using a Bayesian approach it is also possible to obtain more realistic posterior distributions of quantities of interest, such as stock biomass, so that uncertainty can be made more transparent to fishery managers. Knowing the level of uncertainty in assessments is important as it allows managers to avoid fishing strategies which might deplete stocks past minimum biomass levels. This research concluded that grey seal predation was suppressing stock recovery despite a drop in fishing mortality [R6].

3. References to the research (Strathclyde affiliated authors in bold)

- R1** Fernandes, P.G. and **Cook, R.M.** (2013) Reversal of fish stock decline in the Northeast Atlantic, *Current Biology*, 23(15): 1432-1437. <https://doi.org/10.1016/j.cub.2013.06.016>
- R2** **Cook, R.M.** (2019) Stock collapse or stock recovery? Contrasting perceptions of a depleted cod stock, *ICES Journal of Marine Science*, 76(4): 787-793. <https://doi.org/10.1093/icesjms/fsy190>
- R3** **Heath, M.R.** and **Cook, R.M.** (2015) Hind-casting the quantity and composition of discards by mixed demersal fisheries in the North Sea. *PLoS ONE*, 10(3): e0117078. <https://doi.org/10.1371/journal.pone.0117078> [REF2]
- R4** **Cook, R.M.** (2019) Inclusion of discards in stock assessment models, *Fish and Fisheries*, 20(6): 1232-1245. <https://doi.org/10.1111/faf.12408>
- R5** **Cook R.M.** and **Heath M.R.** (2018) Population trends of bycatch species reflect improving status of target species, *Fish and Fisheries*, 19(3): 455-470. <https://doi.org/10.1111/faf.12265>
- R6** **Cook, R.M.**, Holmes, S.J. and Fryer, R.J. (2015), Grey seal predation impairs recovery of an over-exploited fish stock, *Journal of Applied Ecology*, 52(4): 969-979. <https://doi.org/10.1111/1365-2664.12439>

Notes on the quality of research:

All articles are published in the leading international peer reviewed journals in their field of research. The research has been supported with competitively awarded funding, including from the European Commission (Cook (CI), DiscardLESS: Strategies for the gradual elimination of discards in European fisheries, Horizon 2020, 01/03/2015-28/02/2019, GBP65,830) and the Scottish Funding Council (Marine Alliance for Science and Technology for Scotland (MASTS), 01/08/09-31/07/22, overall value GBP17,962,500, Paterson (St. Andrews, Executive Director), Heath (Strathclyde PI)).

4. Details of the impact

Cook's academic reputation has enabled him to make significant and internationally important contributions to sustainable fishing, which is a key factor for food security globally and of major economic importance for many countries. Cook's contributions include assessing fish stocks, reviewing prior fish stock assessments, providing advice in managing major fish stocks and providing guidelines to government in negotiating fish quotas. These activities cover jurisdictions in Europe, North America and Africa, and are exemplified by the following examples of impacts of Cook's work, where a 'fishery' refers to the harvesting of stocks by national fleets.

1. Reassessing the state of west of Scotland cod stocks

The International Council for the Exploration of the Sea (ICES) is the official inter-governmental body for providing scientific advice on fishery management in the northeast Atlantic. EU and Norwegian fisheries management is based on ICES advice. The stocks on which it advises cover over 200 stocks of fish and shellfish that are worth hundreds of millions of pounds at first sale each year. Changes to ICES advice therefore often have significant economic impacts for fisheries.

Until Cook's research, the internationally agreed ICES assessment of the west of Scotland cod stock suggested that the exploitation rate remained very high and that the stock has collapsed. The resulting zero catch limit for cod prevents trawlers from catching associated healthy stocks such as haddock and whiting, with corresponding economic impacts. However, the research reported above suggested that this assessment had not taken into account the significant role of seal predation on cod stocks. Moreover, the 2013 analysis of west of Scotland fish stocks indicated that the stock may have been recovering and that exploitation had reduced substantially since the beginning of the 21st century. The impact of these findings was widely reported in the mainstream press and trade media (e.g. BBC News, The Scotsman, Science Daily, World Fishing and Aquaculture), focussing on the threat posed by seals to fish stock recovery [S1]. In January 2019, ICES agreed to review its assessment of west of Scotland cod in light of Cook's research, and in February 2020 ICES adopted a new model that confirms the reduction in exploitation [S2: references R2, R4 and R6]. As a result of this review, the role of seals is now recognised in ICES advice to the European Commission [S3], which explicitly cites Cook's work [R6].

2. Ensuring the quality of US fish stock assessments

The Center for Independent Experts (CIE) is an organisation funded by National Oceanic and Atmospheric Administration in the USA to conduct reviews of stock assessments carried out by the National Marine Fisheries Service (NMFS). NMFS provides scientific advice to the USA's Regional Management Councils to determine whether their systems of stock assessment provide fishery managers with the necessary information to effectively and sustainably manage fish stocks. This work ensures the quality of assessments in the USA, the world's third largest fish producing nation, and contributes to sustainable development and stewardship of the country's marine ecosystems. As Regional Management Councils are required by US law to manage fisheries in a manner consistent with each fishery's maximum sustainable yield, the work of CIE is intrinsic to the effective and sustainable management of federally owned fish stocks in the USA, which account for the majority of the country's total catch.

The CIE requires highly experienced authorities with an established research track record for reviews. The body of work described above established Cook as a suitable expert, and since 1998 to the present he has consulted on more than 25 reviews covering nearly 100 stocks for all 8 Regional Management Councils of the USA, focussing on a variety of issues from data-poor stock assessments [S4] to modelling discard estimates [S5]. Independent expert reviews such as these are an important factor in fisheries management decision making in the USA. Cook's review of migratory sharks in the Southeast USA, which concluded that the Regional Management Council's assessment failed to sufficiently inform fishery managers, resulted in withdrawal of the assessment and a subsequent revision which explicitly addressed the review comments [S6]. His 2019 review of the Pacific sablefish stock assessment contributed to an understanding that stock exploitation was decreasing rather than increasing, as previously thought. This realisation has allowed the Pacific Fisheries Management Council to raise the advised catch limit for sablefish for the years 2021-2030 [S7], a change which will result in an estimated USD5,100,000 (10-2019) additional catch annually over the said time period.

3. Promoting sustainable fisheries through the Marine Stewardship Council (MSC)

The MSC is an international organisation that promotes good fisheries management practice and sustainable exploitation by encouraging consumers, restaurants and retailers to only buy fish products that have received MSC accreditation, certifying a fishery's environmental and management credentials. Acquiring the accreditation through an initial assessment, and maintaining it via annual audits and five-year reassessments, is demanding but gives suppliers a competitive advantage as it allows their catch to be sold with the sought-after MSC ecolabel. As of 2019, 15% of marine catch worldwide is MSC certified, equating to almost USD10,000,000,000 (02-2019) annually. In the UK, consumers spend nearly GBP1,000,000,000 on MSC products annually, and over 3,500 restaurants serve MSC-accredited products [S8].

Assessing fisheries for MSC certification requires a high level of qualification [S9]. The body of research reported in Section 2 again qualified Cook as a suitable expert, and since April 2016 he has assessed different fish stocks in many locations around the world, including cod and haddock in the North Sea (multi-country), yellowtail flounder in Canadian waters, hake in Namibia, Patagonian toothfish in French Antarctica and halibut in Greenlandic-Canadian waters. For Namibia, for example, Cook was a principal co-author of the assessment that led to MSC certification of the country's hake demersal trawl and longline fishery, the largest fishery in Namibia. Fishing is the third largest sector in Namibia's economy and is expected to grow as a direct result of this certification [S10]. In another example, Cook's evaluation of models used to assess North Sea cod confirmed the stock had been over-exploited by two fisheries and led to suspension of MSC accreditations for both fisheries in October 2019, demonstrating how protection of fish stocks is aided by the MSC process.

4. Influencing UK fishery policy

As a direct result of Cook's reputation in the field, in September 2020 he was invited to participate in a high profile project, commissioned by the UK Government's Department for Environment, Food and Rural Affairs (Defra) and led by the Defra Director of Marine and Fisheries, to establish guidelines for officials negotiating fishing quotas post Brexit. The project report, completed in November 2020, sets out methodology to ensure UK fishery management of stocks shared with other coastal states is compliant with maximum sustainable yield. The resulting document, which includes contributions from Cook, is confidential for understandable policy reasons, though a public version will be published when possible.

5. Sources to corroborate the impact

- S1** Press coverage of analysis of impact of seals on west of Scotland fish stocks:
- BBC News, [‘Grey seals are compromising cod stock recovery plans’](#), 18 May 2015.
 - The Scotsman, [‘Seals to blame for low cod stocks not over-fishing’](#), 18 May 2015.
 - Science Daily, [‘Seals threaten Scottish cod stock recovery’](#), 18 May 2015.
 - World Fishing & Aquaculture, [‘Scottish cod stock recovery threatened by seals’](#), 19 May 2015.
- S2** ICES (2020) [Benchmark Workshop for Demersal Species](#) (WKDEM), ICES Scientific Reports, 2(31), p.17
- S3** ICES (2019) [Advice on fishing opportunities, catch and effort: Cod \(Gadus morhua\) in Division 6.a \(West of Scotland\)](#), p.3.
- S4** Robin Cook (2014) [Report on the Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources](#), prepared for The Center for Independent Experts.
- S5** Robin Cook (2016) [Report on the review of Cumulative Discard Methodology](#), prepared for The Center for Independent Experts.
- S6** National Oceanic and Atmospheric Administration/National Marine Fisheries Service (2013) [SEDAR 34 Atlantic Sharpnose and Bonnethead Sharks: Post-Review Updates](#).
- S7** National Marine Fisheries Service (2019) [Status of the sablefish stock in U.S. waters in 2019](#), acknowledgement of Cook’s contribution on p.68.
- S8** [MSC Annual Report 2018-19](#), p.4.
- S9** [MSC Fisheries Certification Process](#) (2018), pp.52-55.
- S10** Report and press coverage of MSC certification of Namibia’s largest fishery:
- Control Union UK (2020) [Marine Stewardship Council \(MSC\) Public Certification Report for Namibia hake trawl and longline fishery](#).
 - World Fishing and Aquaculture, [‘Namibian Hake Fishery gets blue tick’](#), 18 November 2020.