Institution: Aberystwyth University

Unit of Assessment: 6: Agriculture, Veterinary and Food Science

Title of case study: Application of new genetic methods to support more effective and sustainable fisheries management.

Period when the underpinning research was undertaken: 2011- 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Paul Shaw	Professor	1 May 2011- present
Dr Niall McKeown	PDRA; Lecturer in Marine Ecology	1 July 2011- present

Period when the claimed impact occurred: 2013- 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

The future of multiple fish and shellfish species globally has been secured by research-led improvements in the management of exploited stocks. Advances in DNA techniques have enabled Aberystwyth University researchers to produce genetic definitions of fished stocks and provided the scientific evidence required to effect essential changes to more accurate, and so sustainable, exploitation of wild populations. Fishery managers, governments and NGOs have been empowered through knowledge transfer to implement critical changes to policy and guidelines, resulting in improved fishing practices and a greater understanding of the power of precise genetic information. This has had positive economic benefits to fishing communities and aided conservation of marine biodiversity.

2. Underpinning research (indicative maximum 500 words)

There is a need to improve sustainable exploitation of fishery resources at all scales, from globally important commercial species, to artisanal fisheries vital to local food security. Sustainable supply of food and commercial activity relies on effective management of fished populations, but 90% of fisheries are over-exploited. Fishery management relies on accurate data-based definition of fished stocks. Historical and geo-political delimitations of fisheries do not represent real biological units. Genetic methods of stock description aid definition of biologically meaningful populations, and so better management.

The group led by Shaw, developed genetic approaches, working with fishery managers, government agencies and NGOs, to improve stock definitions and management, and to provide DNA markers for testing the provenance of fishery products i.e., police fishery regulations. The Shaw group has provided stock definitions and advice for finfish, shellfish and cephalopod fisheries in the Western Indian Ocean, NE Atlantic (including UK), North America, Chile, Brazil, South Africa and Angola. Three relationships are provided as examples of impact resulting from this body of work: with the Indian Ocean Tuna Commission (IOTC) and International Commission for the Conservation of Atlantic Tunas (ICCAT) on yellowfin tuna [3.1]; with fisheries managers in regional government in the Falkland Islands [3.2; 3.3] and Wales [3.4]; and with artisanal fisheries managers in the Western Indian Ocean [3.5; 3.6].

The study of yellowfin tuna [3.1] applied novel Next Generation Sequencing approaches. These indicated that the Indian Ocean stock is genetically distinct from the Atlantic stock, and that the

Indian Ocean stock extends into the SE Atlantic, delimited by the biogeographic boundary of the Benguela Current rather than the geopolitical boundary at the southern tip of South Africa (as used at present). The Indian Ocean Tuna Commission (IOTC) and International Commission for the Conservation of Atlantic Tunas (ICCAT), therefore, are using fishery data representing incomplete and mixed stocks respectively, and so potentially mis-managing this important global fishery (2nd most valuable tuna fishery, USD13,900,000,000 point of sale value).

Stock dynamics research in squid and finfish around the Falkland Islands, aided the management of resources vital to the Falkland Islands Government (GBP200,000,000 - GBP250,000,000 ex-vessel value p.a.). Studies [3.2; 3.3] demonstrated important stock boundaries and trans-national extensions of stocks across territorial waters of multiple countries. An aim is to provide data to underpin applications for sustainability accreditation by the Marine Stewardship Council, as achieved for the toothfish fishery (and ongoing).

Application of the fisheries genetics approach to small geographical regions, aimed to define local stock interactions to support development of sustainable supplies of food or commercial activity. Small-scale genetic patchiness in UK and Welsh shellfish populations [3.4] were defined, along with isolation of island populations of cephalopods and fish [3.5] in the SW Indian Ocean. These studies also solved issues of cryptic species, essential for practical management, across the SW Indian Ocean [3.6].

3. References to the research (indicative maximum of six references)

3.1 Mullins RB, Sauer WHH, **Shaw PW, McKeown NJ** (2018) Genomic analysis reveals multiple mismatches between biological and management units in yellowfin tuna (*Thunnus albacares*). *ICES J Mar Sci,* 75, 2145-2152. DOI: 10.1093/icesjms/fsy102

3.2 McKeown NJ, Arkhipkin AI, **Shaw PW** (2019) Genetic analysis reveals historical and contemporary population dynamics in the longfin squid *Doryteuthis gahi*: implications for cephalopod management and conservation. *ICES J. Mar.Sci.,* 76, 1019-1027. DOI: 10.1093/icesjms/fsz009

3.3 McKeown NJ, Arkhipkin AI, **Shaw PW** (2016) Regional genetic population structure and fine scale genetic cohesion in the Southern blue whiting *Micromesistius australis*. *Fisheries Research,* 185, 176-184. DOI: 10.1016/j.fishres.2016.09.006

3.4 McKeown NJ, Hauser L, **Shaw PW** (2017) Microsatellite genotyping of Brown crab *Cancer pagurus* reveals fine scale selection and 'non- chaotic' genetic patchiness within a high gene flow system. *Marine Ecology Progress Series,* 566, 91-103. DOI: 10.3354/meps12044

3.5 Taylor AL, **McKeown NJ**, **Shaw PW** (2012) Molecular identification of three co-occurring and easily misidentified octopus species using PCR-RFLP techniques. *Conservation Genetics Resources,* 4, 885-887. DOI: 10.1007/s12686-012-9665-y

3.6 Healey AME, **McKeown NJ**, Taylor AL, Provan J, Sauer WHH, Gouws G, **Shaw PW** (2018) Cryptic species and parallel genetic structuring in Lethrinid fish: Implications for conservation and management in the southwest Indian Ocean. *Ecology & Evolution*, 1-14. DOI: 10.1002%2Fece3.3775

Research grants

3.7 Shaw, PW; Genetic structuring of sardine and anchovy stocks in the Irish Sea-Biscay area; Cefas; 1 August 2010 – 31 December 2011); GBP32,000

3.8 Shaw, PW; Analysis of population structure of *O.cyanea* from the Western Indian Ocean using analysis of microsatellite variation." PE4/087/2011 Consultancy; ReCoMaP; (1 May 2011 – 31 August 2011); GBP7,000

3.9 Shaw, PW; Genetic structuring of rockcod (*Patagonotothen ramsayii*) populations between the Falkland Islands and southern Chile; Falkland Islands Government; (1 May 2011 – 30 November 2011); GBP17,000

3.10 Shaw, PW; Genomic species definition in SW Atlantic toothfish; Falkland Islands Government; (1 October 2017 – 31 December 2018); GBP16,500

3.11 Shaw, PW; Genetic profiling of Welsh whelks; Welsh Government (Fisheries Section); (1 December 2015 – 31 March 2016); GBP27,964

3.12 Shaw, PW; Genetic profiling of Irish Sea seabass stocks; Welsh Government (Fisheries Section); (1 October 2017 – 31 March 2018); GBP48,018

3.13 Shaw, PW; BLUEFISH: Building resilience into blue growth of the Irish Sea: adaptation to climate change in aquaculture and fisheries; EU Ireland-Wales Intereg; (1 January 2017 – 31 January 2021); EUR6,250,000 (AU allocated EUR1,010,000).

3.14 Shaw, PW; Enabling Sustainable Exploitation of the Coastal Tuna Species (Kawakawa and Skipjack) in the Western Indian Ocean; WIOMSA; (1 January 2019 – 31 December 2021); GBP110,000

3.15 Shaw, PW; Structure, connectivity and resilience in an exploited ecosystem: towards sustainable ecosystem-based fisheries management; NERC Newton Fund; (1 April 2019 – 31 March 2022); GBP1,200,000

4. Details of the impact (indicative maximum 750 words)

Impact on international guidelines and policy

The research by the Shaw group has resulted in changes to international organisation guidelines and influence on policy regarding collection of data and its use in the management of global commercial fisheries. As an example, the study on yellowfin tuna [3.1] was used to inform changes to guidelines [5.1] on fisheries data gathering and analysis by the Indian Ocean Tuna Commission (IOTC), and transfer to the International Commission for Conservation of Atlantic Tunas (ICCAT). As an invited External Expert, Shaw put to the IOTC Working Parties that their international boundaries, and so landing statistics and management models, should be changed to reflect the biogeographic rather than geopolitical boundary between the two areas and their yellowfin tuna stocks. These recommendations were accepted by IOTC [5.1]. This also resulted in knowledge transfer to, and changed awareness and practices of, these bodies and linked organisations such as the World Wildlife Fund (WWF) [5.2], to use fisheries genetic methods to underpin science-based policy: *"In light of these results from South Africa, the WPDCS REQUESTED that similar projects are implemented for fleets that operate in the South-eastern waters of the Atlantic ocean.."* [5.1]. International (WIOMSA) and national (DSFA, Tanzanian Government) organisations in the western Indian Ocean region have also changed awareness and practices of the use of fisheries genetic methodologies, issuing calls for stock structuring studies on further tuna fishery species [5.2; 5.3].

Changes to the IOTC and ICCAT boundaries from November 2019 will have significant impact on how tuna should be managed, particularly in the Indian Ocean. At present yellowfin tuna are listed globally as "Near Threatened", with the Indian Ocean stock recognised to be experiencing overfishing, whilst Atlantic stock is not. If landings fished from the SE Atlantic area, currently listed with ICCAT, are recorded as Indian Ocean stock (IOTC) landings, then the position of the IOTC stock will be recognised as even more threatened with collapse. The yellowfin tuna industry is a vital artisanal fishery, and foreign currency earning, commercial enterprise for a number of developing countries around the Indian Ocean, so sustainable management based on accurate stock definition is essential to future food and commercial security of the area.

Impact on policy

Research by the Shaw group has also had impact on practice and policy regarding management of regional commercial fisheries. On the basis of previous published studies conducted for Defra and Cefas, the Welsh Government commissioned Shaw to conduct studies of fisheries genetics of whelk, seabass, brown crab and razor clam populations in Welsh waters to inform their sustainable management of these resources [5.4- 5.7]. The data and advice from these studies have been used in preparation for post-Brexit negotiations on reopening of the seabass fishery, and in whelk fishery management through changes to policy and regulations on minimum landing sizes [5.5; 5.6].

Impact on practitioners

A second example of impact on government institution management of regional fisheries is a series of research projects commissioned by the Falkland Islands Government [3.9; 3.10]. The resulting knowledge transfer [3.2; 3.3] and input to management of commercial fisheries resources were vital to the Falklands economy, as this constitutes 50% of their annual GDP. Based on earlier studies of toothfish (Shaw et al. 2004) that resulted in Marine Stewardship Council sustainable fishery accreditation of the South Georgia fishery, the aim since 2011 has been to apply similar studies to wider areas and different species of finfish (e.g. Southern Blue Whiting, Rockcod) and cephalopods (Shortfin squid), to better define transboundary stocks across territorial waters of the Falklands, Argentina and Chile. As the Falkland Islands fisheries use a sustainable management method based on Total Allowable Catch linked to real-time catch data, it is vital that the geographical and demographic definition of fished stocks is accurate in the models used. The resultant knowledge transfer, data and advice have helped refine models for sustainable catch regulation for the Falkland Islands Government and fisheries managers, leading to increased sustainability and commercial value. [5.8]

Impact on practitioners, economy and bio-diversity

Research by the Shaw group has also had direct impact on fishery management. As an example, the Rodrigues octopus fishery in the Indian Ocean had been in decline over many years due to over-exploitation and there was urgent need to improve its management. A study by Shaw and McKeown, commissioned by ReCoMap [5.9] established that the Octopus population of Rodrigues was isolated from other populations in the SW Indian Ocean, and therefore unlikely to be replenished by larval input from external sources if the Rodrigues population crashed due to overfishing, as predicted by fishery statistics. This finding, together with other fishery data, was used by the local administration [5.10] to change policy in implementing a series of closures to fishing (2012-14), that resulted in 26-49% increases in landings and a USD173,000 increase in export earnings for the local community, plus avoidance of the predicted stock crash [5.11]. The knowledge transfer and success of the closure system implemented has been adopted by the local community and resulted *"….in a longterm change in fishing behaviour and management practice"* [5.11]. This management approach has resulted in both sustainable management and improved local incomes from artisanal fisheries.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Use of research data and analysis (Mullins et al. 2018) [3.1] to inform changes to guidelines on fisheries data gathering and analysis by Indian Ocean Tuna Commission (IOTC, and transfer to International Commission for Conservation of Atlantic Tunas - ICCAT): citation in reports of 2019 Working Party on Tropical Tunas (WPTT) and 2019 Working Party on Data Collection and Statistics (WPDCS), p.23-24 and p.35: https://www.iotc.org/sites/default/files/documents/2019/12/IOTC-2019-WPDCS15-RE_FINAL_0.pdf (November 2019)

5.2 MASMA "Enabling Sustainable Exploitation of the Coastal Tuna Species (Kawakawa and Skipjack) in the Western Indian Ocean": https://www.wiomsa.org/ongoing-project/enabling-sustainable-exploitation-of-the-coastal-tuna-species-kawakawa-and-skipjack-in-the-western-indian-ocean/

5.3 Tanzanian Government (DFSA) "Stock Structure and Genetic Connectivity of Tuna and Tuna Like Species in Tanzanian EEZ, Territorial and Internal waters": https://blog.wiomsa.net/wp-content/uploads/2019/04/EoI-Notice_stock-connectivity_11apr19.pdf (11/04/2019)

5.4 Delivery of report on commissioned research to Welsh Government Marine & Fisheries Section: Shaw & McKeown (2016) "Genetic Profiling of Welsh Whelk (Buccinum undatum) populations." *Report to Welsh Government (C128 2015/2016)*. 9pp

….which contributed to:

5.5 "Welsh Government Consultation Evidence Review: Sustainable Management of the Welsh Whelk Fishery" (March 2017): https://gov.wales/sites/default/files/consultations/2018-01/evidence_base_doc-en.pdf

5.6 Legislative change in fisheries in Welsh waters http://www.senedd.assembly.wales/documents/s90424/EM%20SL5425%20-%20The%20Whelk%20Fishing%20Wales%20Order%202019.pdf (25/06/2019)

5.7 Testimonial from the Senior Scientist, Welsh Government Marine & Fisheries Section (now SSO for Welsh Government Office for Science), regarding impact of commissioned fisheries genetics research on WG debate and guidelines on fisheries policy. (18/12/2020)

5.8 Testimonial from The Chief Fisheries Officer of the Falkland Islands Government (Fisheries Division) regarding impact of commissioned fisheries genetics research on ways of working and sustainable fisheries management. (04/02/2021)

5.9 Delivery of report on commissioned research to EU programme on Regional Coastal Management Programme of the Indian Ocean Countries (ReCoMaP): Shaw PW (2011) ProGeCo report_Analysis of population structure of *O.cyanea* from the Western Indian Ocean using analysis of microsatellite variation. 7pp.

…which led to:

5.10 commissioning of a trial programme of fishery closures on the island of Rodrigues, as reported in Jhangeer-Khan R., Agathe, H. & Yvergniaux, Y. (2015) "Managing octopus fisheries through seasonal closures: A case study from the island of Rodrigues". *Blue Ventures Conservation Report*: bjyv3zhj902bwxa8106gk8x5-wpengine.netdna-ssl.com/wp-content/uploads/2017/01/Jhangeer-Khan_et_al_2015_Managing_Octopus_Fisheries_Through_Seasonal_Closures_Rodrigues.pdf

5.11 Testimonial from Fisheries & Marine Protected Areas Specialist, EU Regional Coastal Management Programme of the Indian Ocean Countries (ReCoMaP). (02/10/2020)