**Institution:** University of Plymouth

**Unit of Assessment:** UoA6

**Title of case study:** Global Climate Impacts Assessments for Biodiversity: Developing New Tools and Shaping National and International Policy

**Period when the underpinning research was undertaken:** 2002 - 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: |
|---|---|---|
| Camille Parmesan | Prof: NMA Chair in Public Understanding of Marine Science & Human Health, Plymouth University | 01/01/2011 - present |
| Mick Hanley | Assoc. Prof in Plant-Animal Interactions | 01/12/2005 - present |
| Michael Singer | Professor of Evolutionary Ecology | 01/05/2013 - 30/05/2017 |
| Mick Fuller | Prof in Plant Physiology | 01/08/2002 - present |

**Period when the claimed impact occurred:** 01.08.2014 – 11.11.2020

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

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

Parmesan and colleagues have developed novel methodologies to rigorously assess the degree to which human-driven climate change has driven long-term changes in natural and managed systems. Their research led to a paradigm shift in how to assess impacts, specifically leading to much higher confidence in linking warming trends to changes being observed in wild species and agricultural systems. This research provided key evidence for determination of a 2°C limit for "dangerous" climate change in the Copenhagen Accord (2009) and again for the Paris Accords (2015) under the United Nations Framework Convention on Climate Change (UNFCC). Research by Parmesan and others has also formed the evidence basis for multiple legal proceedings against the United States Government, at least one of which is destined for the U.S. Supreme Court, and has the power to change Federal laws on greenhouse gas emissions.

**2. Underpinning research** (indicative maximum 500 words)

Research at University of Plymouth (Drs Parmesan, Hanley, Singer and Fuller) has been instrumental in assessing the impacts of anthropogenic climate change on wild species and agricultural systems both in the UK and globally [3.1-3.9]. Parmesan began this research area as Professor at the University of Texas at Austin, USA (to 2010) and continued as Professor at University of Plymouth (from 2011). As part of assessing these impacts, new approaches had to be developed for linking the observed changes to climate change *vs.* other drivers. As Lead Author in the Intergovernmental Panel on Climate Change (IPCC) 3rd Assessment Report (2001), Parmesan argued that the modelling approach then in use for "attribution" of observed changes to anthropogenic climate change, originally developed by climatologists, was inappropriate for assessing its impacts. Parmesan developed a different approach using

inductive reasoning based on multiple, independent lines of evidence (from first principles to experiments to examination of detailed patterns in long-term datasets) [3.1].
For natural biological systems, Parmesan's research argued that:
(1) It is possible to attribute observed local change to changes in local/regional climate, but "attribution" to human-driven climate change requires studies at the same global scales as climate models. For wild species, whose distributions are typically across areas less than one continent or ocean, a global-scale assessment is possible only through meta-analyses of many species distributed across different continents and oceans [3.1- 3.4].
(2) Strong "attribution" to climate change is possible with observational datasets when:(i) species can be found that have few other human impacts such that confounding effects are minimized (*e.g.* little habitat lost), (ii) multiple lines of evidence are assessed (*e.g.* physiological thresholds, lab experiments on thermal optima, paleological information and results from modeling approaches, as well as observed long-term ecological changes) and (iii) evidence from multiple approaches point to climate change as the main driver of observed biological change [3.1- 3.4].

Using this global multi-evidence approach, research at UoP has provided clear, irrefutable evidence that wild species have been impacted by relatively modest recent warming of < 1°C globally [3.1, 3.2, 3.4], that marine systems have had a stronger response than terrestrial systems [3.3] and that these biological changes have had a negative impact on human health and food security [3.5, 3.6]. Parmesan and colleagues further demonstrated that proportions of wild species impacted by climate change had been under-estimated in previous assessments.

The first breakthrough was achieved by demonstrating that for plants needing cold winters to "reset" their clocks ("vernalization"), winter warming drove delays in spring flowering. Taking this effect into account raised the estimated level of impacts from 72% up to 92% of species [3.7]. Complementary research by Hanley and Parmesan showed that responses of plants to combinations of rising carbon-dioxide, rising temperatures and altered patterns and variability of both temperature and precipitation are complex and have countered conventional thinking about simple effects [3.2]. Parmesan and colleagues also discovered that controlled environment experiments tend to under-predict these complex 'real' responses [3.4].

This research on natural systems provided a clear causative link between observed biological changes and human-driven climate change. Conversely, in agricultural crops, rapid adaptation to recent climate change was already in evidence, primarily through behavioural changes of farmers and advances in plant breeding. In spite of this, Parmesan, Hanley and Singer showed that real-life complexities documented in earlier studies [3.1, 3.2, 3.4, 3.7] have led to some crop models underestimating the actual (observed) impacts of climate change on crop plants [3.8]. Fuller, in association with colleagues at Horticulture Research International, improved upon simple temperature-based crop models by incorporating effects of rising $CO_2$. They showed future climate change affected multiple aspects of crop biology, altering development, physiology and phenology, which in turn were projected to impact date of maturity and yield [3.9].

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


3. 1 **Parmesan, C.**, C.M. Duarte, E.S. Poloczanska,, A.J. Richardson, D.S. Schoeman, **M.C. Singer** (2013). Beyond climate change attribution in ecology and conservation research. *Ecology Letters,* Special Issue "The Ecological Effects of Environmental Change." 16(S1), 58-71.

3.2 **Parmesan, C. & Hanley, M.** (2015). Plants and climate change: Complexities and surprises *Annals Botany* 116(6):849-864.

3.3 Poloczanska, E.S., C.J. Brown, W.J. Sydeman, W Kiessling, D.S. Schoeman, P.J. Moore, K. Brander, J.F. Bruno, L. Buckley, M.T. Burrows, C.M. Duarte, B.S. Halpern, J.Holding, C.V. Kappel, M.I. O'Connor, J.M. Pandolfi, **C. Parmesan**, F. Schwing, S.A. Thompson, A.J. Richardson (2013) Global imprint of climate change on marine life. *Nature Climate Change*. 3(10):919-925.

3.4 Wolkovich, E.M., B.I. Cook, J.M. Allen, T.M. Crimmins, J.L. Betancourt, S. Travers, S. Pau, J. Regetz, T.J. Davies, N.J.B. Kraft, T.R. Ault, K. Bolmgren, S.J. Mazer, G.J. McCabe, B.J. McGill, **C. Parmesan**, N. Salamin, M.D. Schwartz & E.E. Cleland (2012). Warming experiments underpredict plant phenological responses to climate change. *Nature* 485(7399):494-497.

3.5 Hansen, J., P. Kharecha, M. Sato, V Masson-Delmotte, F. Ackerman, D.J. Beerling, P.J. Hearty, O. Hoegh-Guldberg, S-L. Hsu, **C. Parmesan,** J. Rockstrom, E.J. Rohling, J. Sachs, P. Smith, K. Steffen, L. Van Susteren, K. von Schuckmann, J.C. Zachos (2013). Climate change and intergenerational justice: Rapid reduction of carbon emissions required to protect young people, future generations and nature. *PLoS ONE*

3.6 Duffy, P.B, C.B. Field, N.S. Diffenbaugh, S.C. Doney, Z Dutton, S Goodman, L Heinzerling, S Hsiang, S.B. Kapnick, E Lentz, D.B. Lobell, S Myers, L.J. Mickley, S.M. Natali, **C Parmesan**, R Thieler, S Tierney, A.P. Williams (2019). Science supporting an endangerment finding for atmospheric greenhouse gases: an update. *Science* 363 (6427):597-609

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

<u>Impact on assessing "attribution" for detected changes in species and ecosystems, and in assessing overall effects of climate change on marine and terrestrial organisms, particularly in the IPCC</u>

As a member of Working Group II ("Impacts, Adaptation and Vulnerability") for IPCC since 1997, Parmesan has contributed original research evidence, assessed global impacts for diverse systems, and changed the way that IPCC approaches assessments for the impacts sectors (particularly for natural and managed biological systems) [5.1, 5.2]. Parmesan's novel methodologies were recognised in IPCC AR5 (2014) as a paradigm shift in assessing "attribution" and subsequently adopted for Working Group II (IPCC 2014, chapter 18 "Detection and Attribution") [5.1, 5.3]. In his supporting letter, Prof. Cramer stated that *"Her approach to attribution was designed specifically to deal with the difficulties in assessing causation from correlation, using comparatively sparse observations. Parmesan's research on the problems of attribution in natural systems was key to the development of attribution assessments for biological systems in AR5."*

Parmesan's approach has now become the standard for IPCC AR6 (Second Order Draft publicly available for review starting December 4, 2020), for which Parmesan is a Coordinating Lead Author [5.1, 5.2, 5.5]. In the words of Prof. Andreas Fischlin [5.2], *"This systematic approach as developed in Parmesan & Yohe 2003, was later expanded in several papers[2], herewith defining the requirements for rigorous attribution.... Parmesan's work continues to provide a basis for attribution in the IPCC assessments, particularly when it comes to analysing the recent, increasingly more abundant changes in natural and managed systems.... This continues to be a standard for climate science including the IPCC assessments up to the present as this is the case e.g. for the current IPCC Sixth Assessment Report (AR6, in review)."* This judgement is corroborated by Prof. Cramer, and he states in his letter that *"Her approach continues to be the foundation for biological impact assessments in the IPCC 6th Assessment Report (AR6)..."*

Additionally, original research of Parmesan and collaborators informed IPCC assessments of the extent and magnitudes of impacts of recent climate change for marine and terrestrial systems. Prof. Wolfgang Cramer [5.1] referred to Parmesan as: *"the 'go-to' person for global climate change impacts."* A suite of 16 publications authored by Parmesan was highly influential in giving *"very high confidence"* to the statement that human-driven climate change had impacted wild species globally in the 5th IPCC Assessment Report (2014) [5.1-5.4]. A subsequent IPCC Special Report on Global Warming of 1.5 had the difficult task of assessing the differences in impacts at 1.5° C warming above pre-industrial *vs.* higher levels of warming when there had been very few modelling studies of this low a level of warming. UoP research documenting recent response of species to 0.7° to 1.0°C warming, particularly Parmesan and Hanley's recent global synthesis of responses of plants [3.2], were crucial in IPCC assessment

of impacts at these lower levels of global warming. Fischlin's letter [5.2] remarked on this: *"Notably the Special Report on 1.5° global warming as prepared on request by the UNFCC, has based part of its assessment on Parmesan and Hanley 2015 global synthesis of ecological and evolutionary impacts of climate change on plants."* Fischlin concluded with a summary of the impacts of Parmesan's long history of research on responses of plants and animals to anthropogenic climate change: *"These studies form an essential part of the body of evidence for the IPCC conclusion in its last Synthesis Report (AR5) of* "very high confidence" *in the marine and* "high confidence" *in the terrestrial realm that anthropogenic climate change has altered species' distributions and seasonal timings."*

Attribution for agricultural systems, in contrast, demonstrated the power of human-led adaptation to minimize negative impacts of climate change. Using Parmesan's approach, IPCC concluded that human-driven climate change had a much lower impact on crop systems than on natural systems globally [5.3, 5.4].

Cramer [5.1] noted that Parmesan's research also has had a major influence on other international assessment process, particularly the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), stating *"the work of Camille Parmesan is part of the very foundation of these assessments, with profound consequences for international policy."*

<u>Impact on the evidence base for the United Nations Framework Convention on Climate Change (UNFCC)</u>

This body of research has also been used to support the UNFCC 2° limit for "dangerous" climate change, beyond which extinctions of a substantial proportion of species is inevitable and whole ecosystems risk collapse, and to support the finding of greenhouse gases as the primary cause of this endangerment [5.1-5.4]. This research formed part of a summary product of the UN Climate Change Conference of the Parties (COP21) in Paris (2015), in which Parmesan's paradigm shift was highlighted [5.6]. . The research contributed to affirmation of a 2° limit to dangerous climate change, as well as to efforts to limit global warming to 1.5° above pre-industrial levels, designated in the Paris Accords [5.1, 5.2 & 5.6]. These internationally agreed global temperature limits dictate necessary greenhouse gas reductions required by nations to ensure that these limits are not exceeded.

Fischlin remarked on this in his letter [5.2], stating "*Such key findings from IPCC have shaped the understanding of UNFCC negotiators, which led eventually to the decision by the Parties to limit global warming at a low level such as well below 2°C and if possible even at 1.5°C above preindustrial levels (UNFCC Paris Agreement 2015)."*

<u>Impact on legal proceedings against the USA government for failure to reduce greenhouse gas emissions.</u>

The UNFCC Paris Accords were signed in 2015 and ratified by 189 nations, but the USA Government pulled out in 2017, questioning the finding that rising levels of greenhouse gases constituted "dangerous climate change." Research by Parmesan and others has formed the evidence basis for multiple legal proceedings against the United States Government, all of which are currently on-going [5.7-5.10].

The first set of lawsuits is by the Environmental Defense Fund. Our 2019 publication [3.6] delivered more recent evidence supporting the 2009 United States Environmental Protection Agency (EPA) "Finding" (legal ruling) that greenhouse gases are pollutants that require regulation. Specifically, [3.6] analysed new evidence and provided rigorous validation that rising greenhouse gases are an endangerment to public health and welfare. Parmesan's role was to synthesize new evidence, published since the 2009 EPA Ruling, on the impacts of climate change on ecosystems. Our research is currently being presented as expert evidence in multiple lawsuits against the EPA (begun under the Trump administration), in response to its recent moves to overturn its own 2009 ruling (under Obama) [*e.g.* 5.7]. By this

reversal, the current EPA is severely undermining efforts to reduce U.S. greenhouse gas emissions.
The second set of lawsuits has been brought by the NGO *Our Children's Trust*, starting in 2014 and continuing to the present. They rely on research and Amicus Briefs by Parmesan and others on the impacts of human-driven global warming [*e.g.* 5.8-5.10]. The most recent iteration, the "Youth Amended Complaint", is directly suing 13 Directors of USA government agencies that are relevant to greenhouse gas emission regulation. On January 17, 2020, the Ninth Circuit Court recognized the gravity of evidence on injuries from climate change and the government's role in causing them, but found the government did not have power to address these injuries. The case has been appealed to a higher Court. At least one of these court cases will likely be heard by the U.S. Supreme Court, which has power to change Federal laws regulating USA greenhouse gas emissions.

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


5.1 Letter from Prof. Wolfgang Cramer
5.2 Letter from Prof. Andreas Fischlin
5.3 IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
5.4 IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
5.5 IPCC, 2022: Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC) [Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E., Mintenbeck, K., Nicolai, M., Okem, A., Petzold, J., & Rama, B. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA *(in review and under revision)*
5.6 Parmesan was a plenary speaker at pre-COP21 science meeting "Our Common Future under Climate Change (CFUCC)", organized by UNESCO, Future Earth, and ICSU (2,000 participants, Paris 2015). Excerpts from Parmesan's CFUCC talk were highlighted in the CFUCC film shown at COP21 in Paris 2015 (17 min): https://www.youtube.com/watch?v=OSQfUgzXFYk&feature=youtu.be&list=PLsW11BW1_aTp0zT8uTTFFt9BPAElUPA8D&index=1
5.7 Union of Concerned Scientists Amicus Brief 24 April, 2020
5.8 Our Children's Trust Amicus Brief, 27 Oct. 2014 (Parmesan's initial Testimony)
5.9 Our Children's Trust Case Appeal, 3 March, 2020 (relies upon **[3.5])**
5.10 Our Children's Trust Press Release, 3 March, 2020