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Dr. David Tripp
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9 February 2016

Dear Dr. Tripp;

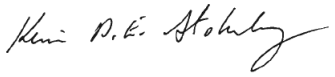
Thank you for giving me the opportunity to review this research project. As you requested on 11 December 2015 I have examined the academic work on fishery impact relevant to the proposal for new fisheries management measures. That work was undertaken by a team led by Professor Michel Kaiser at Bangor University, and published as items 59, 60 and 61 ("Cardigan Bay Fishing Intensity Study"). After reading "Scallop Fishing in Cardigan Bay New Management Measures," I focused on those documents entitled "Impact of scallop dredging on benthic communities and habitat features in the Cardigan Bay Special Area of Conservation Part I-Impact on infaunal invertebrates, Part II-Physical environment, Part III-Impact on epifauna."

As a brief background, I am a professor and the Chair of the Department of Fisheries Oceanography in the School for Marine Science and Technology at the University of Massachusetts Dartmouth. I am responsible for developing and supervising the SMAST Fisheries programs including research on groundfish, lobsters and scallops. My primary research focus is the sea scallop program, which includes stock assessment, rotational fishery management strategies, growth and mortality estimates, gear development and environmental assessment. Our data have been used in sea scallop fisheries management plans and the Habitat omnibus here in New England. I am also the Chair of the ICES working group on scallops and I have served as a consulting for the Scottish government on the SAC Firth of Lorn area including a BACI study examining dredging impacts.

My previous research projects dealt to a large extent with environmental impact studies, include co-principle investigator of the SEA Herring project examining the horizontal and vertical spatial distribution of Pacific herring (*Clupea pallasi*) and determine the underlying biological and physical variables influencing this distribution in Prince William Sound Alaska and the impacts the *Exxon Valdez* oil spill; coordinating the fish, macroinvertebrate (*Penaeus aztecus* and *Callinectes sapidus*) and water quality components of the EMAP (EPA/NOAA project) in North Carolina's coastal estuaries to provide a baseline data set for measure environmental impact; examining the structure and dynamics of the giant scallop (*Placopecten magellanicus*) population in the Baie des Chaleurs, Québec; surveying and analysis of existing rockweed (*Ascophyllum* and *Fucus* spp.) resources along the coastline Southern New Brunswick, Canada; environmental impact studies of mortality inflicted by hydro-turbine dams on anadromous fish populations; examining inter- and subtidal fish and invertebrate community structure in temperate coastal waters. I have published 50 scientific papers and 5 book chapters on these research projects.

Attached is my review following the "Scallop dredging of Cardigan Bay – Peer scientific review of underpinning data and evidence." Please contact me at the above address if I can provide any further information. My office phone number is (508) 910-6373 and my email address is kstokesbury@umassd.edu.

Sincerely,



Kevin D. E. Stokesbury, Ph.D.
DFO Professor and Chair

Scallop Dredging of Cardigan Bay – Peer Scientific Review of underpinning data and evidence. (K. D. E. Stokesbury 8 February 2016).

I have examined the documents, "Impact of scallop dredging on benthic communities and habitat features in the Cardigan Bay Special Area of Conservation Part I-Impact on infaunal invertebrates, Part II-Physical environment, Part III-Impact on epifauna" which detail the Cardigan Bay Fishing Intensity Study lead by Professor Michel Kaiser at Bangor University. This work is of the **Highest Scientific Merit**. The authors state that their BACI experiment is one of the most substantial scallop dredging impact experiments conducted in the UK and worldwide. I agree. It is the most thorough, well executed, Before-After-Control-Impact study I have seem. The documents are extremely well written, they include clear statement of the objectives for each section; a well thought out conceptual model with well-defined testable hypotheses; a carefully planned experimental design, the BACI structure is based on current knowledge, both scientific and from fishing practices; high statistical rigor and sound logic for analyses; clear presentation of the methods and results; and a specific conclusion for each experiment stating the results of the hypotheses tested. The three components of the experiment, infauna, physical environment, and epifauna, are discussed separately and then combined in a discussion, which also compares and contrasts their findings to other similar research projects around the world. This research project meets the criteria for "Best Available Science for fisheries and environmental science, policy and management" as defined by Sullivan et al. 2006.

1. Relevance to proposed Welsh Government Policy.

In "Scallop Fishing in Cardigan Bay – New Management Measures" the Welsh Government proposes establishing a scallop fishery within the Cardigan Bay SAC, incorporating the area, which is currently closed to scallop fishing, as the seasonal open area (the Kaiser Box). The management proposal was based on the results of the Bangor University BACI study. These results are described briefly but exactly under the section Evidence of Change –Scientific Research (page 2 and 3). As the management proposal follows the advice derived from the scientific study, the study is highly relevant to Welsh Government Policy.

2. **Scientific Objectives:**

The objectives are clearly defined, well thought out and scientifically sound. The overall objective was to examine the response of the geology of the seabed, and the animal communities living in and on the seabed to a gradient of scallop fishing activity. The researchers did this by breaking each component down into a series of testable hypotheses. Both the immediate impacts of fishing and the subsequent effects after a 4 month period were measured.

The inter-dependencies between objectives were well identified. The hypotheses for infaunal and epifauna followed the same structure beginning with an examination of the spatial gradient (of sediment and animals) of the area prior to the experimental impact. Once spatial autocorrelation was defined the researchers examined the impact of fishing on the composition of animal communities and the resilience of these species to fishing intensity through a series of 4 sub-hypotheses testing overall species composition, species richness, species persistence and colonization rates, and possible extinction of any species. Following this community level hypothesis the impact of fishing intensity on biomass and abundance of animals within the communities was examined. Then the impact of fishing intensity on the functional groups and functional traits was examined. Finally in the 5^{th} hypothesis the impact of fishing intensity on sediment composition of the seabed and how that might effect animal community composition was examined. This is a very effective structure designed progressing from overall general impact detections to specific effects.

The researchers also used side scan sonar to identify fishing activity and the amount of disturbance to the seabed. As the authors note this is extremely important as the persistence of fishing marks depends on the sediment, environmental conditions and the nature of the impact.

3. Scientific Approach and Methodologies:

The chosen methodologies are scientifically sounds and well considered. This research follows a BACI design; in this case there are 4 control sites and 4 sites at each level of fishing intensity (low, medium and high, Table 1 and Figure 2). The BACI design assumes that the control and impact sites have similar animal communities, and environmental conditions, and that these communities will change over time in the same fashion, except for any disturbances caused by scallop dredging in the impact areas. The researchers tested specifically for this with their first hypothesis; they did not find any autocorrelation with infauna or sediment composition (section 3.2.1.4, page 20 Part I). They did find a gradient over the area for epifaunal suggesting that sites that would be highly fished were already different prior to fishing. This is somewhat surprising as they randomized their sites which should have prevented this. They concluded that the gradient was not related to fishing intensity and would not affect the experimental analysis (3.1.1.4 page 12 Part III).

The optimal BACI design uses a two-way analysis of variance (two-way ANOVA) where the interaction between site and time is used to statistically detect an impact (Green 1979). However, the two-way ANOVA is only reliable if densities in the control and impact areas are equal. This is rarely the case in marine field studies and the statistics involved to deal with inequality are complex and controversial. Several researchers have suggested using only graphs and tables to indicate environmental impacts while others recommend statistical tests which are usually limited to t-tests and one-way ANOVAs (Green 1979, Stewart-Oaten et al. 1986, Underwood 1994). Here the researchers did not use a two-way ANOVA, instead they addressed the challenges of the BACI design by applying a series of well thought out and justified statistical tests. These included a Principal component Analysis for sediment samples; Partial mantel correlogranms dissimilarity matrix using the Bray Curtis index for autocorrelation and later fishing intensity gradients, Permanova and between group analysis for differences between sites for sediment and taxa followed by a Simper analysis to distinguish taxa; species accumulation curves to visualize taxa richness variations between surveys followed by linear regressions and ANOVA analysis; Generalized additive models for abundance and biomass differences; and RLQ-ordination methods to examine relationships between taxa functional trait composition of the communities and environmental variables. These statistical tests were briefly described in the text with complete references and links for additional information. Combined they represent a very thorough analysis of the data set.

One of the few suggesting I have that might add to the text improving the clarity of the experiments data set is to provide further information on Table 2 in both Parts I and III. As it stands now the tables present the summary of biological data collected for infauna and epifauna, grouped for each survey. These present very good overall estimates with low CV's and excellent ranges of relative precision, i.e. between 2% and 12% for the infauna table. However, it would be helpful to see a table that presents these same columns but for each fishing intensity. For example:

			Sp number			Abundance			Biomass	
		n	mean	SE		mean	SE		mean	SE
Mar-14	control									
	Low									
	medium									
	height									
14-May	control									
	Low									
	medium									
	height									
14-Sep	control									
	Low									
	medium									
	height									

Then the relative precision of each experimental unit could be easily assessed as this is the level of statistical comparison for the BACI.

4. Results and Conclusions:

Have the results been collected in a standardised way? Are the data statistically robust? Are the statistical tools utilized sufficient? Have the data been interpreted with sufficient critical evaluation? Have any data quality issues been identified? Are the conclusions drawn sufficiently supported by the data?

The short answer to all these questions is "YES." The experimental design for this work was carefully laid out, with sufficient samples for both infauna and epifauna. The Fishing intensity was set up in a gradient and carefully documented (Table 2 and Part II). Because the experiment was conducted so carefully the data set is statistically very robust and the choice of statistical tests are clearly explained and test the hypotheses effectively. The assumptions of the experimental design were also statistically examined and explained (i.e. Hypothesis 1). The resulting conclusions are well supported by the data and analysis.

My one comment in the analyze concerns the target species of the fishery, the King Scallop (*Pecten maximus*). (Note: the king scallop is not identified in any of the 3 Impact documents, referred to only as "scallop dredging" for example, but in the species list the only scallop listed in the Queen scallop *Aequipecten opercularis*, in Table 3, page 8 Part III; this might lead to some confusion). Table 3 of Part III lists the abundance, biomass and occurrence of the most common species in the beam trawl for the 3 surveys combined down to 4.67 grams per $100m^2$ at 2% occurrence for *Scyliorhinus stellaris*. Table 2 of Part I summarizes the cost and logistics and states that 29.6 tonnes of scallop meat and gonad were harvested from the 13 fishing intensity impact sites. So given the size of each of these sites (1700 m by 370 m, page 11, Part I) there should be roughly 3.3 grams of scallop (meat and gonad) per m^2, making the King scallop the most abundant epifauna species, at least before the fishing event. How was this dealt with? Was the target species not included in the analysis or was it not sampled in the beam trawl during any of the surveys? Some discussion of this would be useful as the scallop itself is an important member of the epifuanal community.

At the risk of self-promotion on page 56 in the discussion on BACI studies addressing the effects of the entire fishing ground my study (Stokesbury and Harris 2006) could be cited as an example. We found that the epibenthic community of the closed areas of Georges Bank did not appear to be detrimentally effected by a limited sea scallop fishery, examined using a BACI design. Shifts in taxonomic categories and individuals within categories within the areas where the fishery was executed were similar to those in the unfished control areas. Further, the sea floor sediment composition shifted more than the epibenthic community it supports. Therefore, our study suggested that a limited fishery mimicking natural environmental fluctuations may alter the epibenthic community less than continuous fishing pressure over time. These conclusions agree with the conclusions of the present study.

5. **What is the overall quality of the evidence?**

Are the conclusions drawn from the study of sufficient quality to be utilised to inform the Welsh Government Policy.

The overall quality of the evidence produced from this experiment is EXCELLENT. The conclusions are carefully presented and discussed. They are also compared to the greater literature. The finding from each of the three documents are clearly and directly stated in the Executive Summary and reproduced in the "Scallop Fishing in Cardigan Bay New Management Measures." I have not seen a better executed BACI study. I meets the standards of "Best Available Science' and should be used to guide marine management and policy.

Literature Cited:

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Sullivan PJ, Acheson JM, Andermeier PL, Faast T, Flemma J, Jones CM, Knudsen EE, XMinello CM, Secor DH, Wunderlich R, Zanetell BA. (2006) Defining and implementing best available science for fisheries and environmental science, policy, and management. American Fisheries Society, Bethesda, Maryland, and Estuarine Research Federation, port Republic, Maryland.

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