

**The need of decoding life for taking care of biodiversity and the sustainable use of nature in the Anthropocene – a Faroese perspective**

**by**

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version #3

Dear Dr Stephen Richards,

PCI Genomics Recommender

We would like to thank for the opportunity to revise the manuscript. We would also like to thank the reviewers for their comments. We have substantially revised parts of the manuscript, and at places added more information and new references. Thus, the number of references has increased from 95 to 111.

The authors have had lively discussions. One of the authors in the original manuscript, Sjúrdur Hammer, would have like the manuscript to be directed considerably more towards classic conservation problems and considerably less towards commercial species. However, as Faroe Islands have two commercial species among the ERGA Pilot species, it is natural that the manuscript has a sizeable attention to commercial species and management. This is in full accordance with the Convention on Biological Diversity ("the conservation of biological diversity and the sustainable use of its components"), to which the present Faroese Government recently confirmed their commitment. Therefore, the approach in the manuscript is the same as before, and Sjúrdur Hammer has consequently asked to be moved from the author list to the Acknowledgments.

Our answers and comments to the reviewers' reports are found below.

We hope that the Recommender and reviewers will be satisfied with our revisions and our answers to their comments.

On behalf of the authors,

Sincerely,

Svein-Ole Mikalsen

## Our comments to the reviewers' reports

### Reviewer 1:

#### *Horizontal expressions...*

This text, and especially the background/introduction is aimed at a broad audience, not only biologists of molecular and ecological shades. For such a broad audience, we think it is important to underline that genetic diversity is underlying biodiversity, so we prefer to use a few sentences to sketch these frames. Otherwise, with the numerous rewritings throughout the manuscript, we hope the reviewer will have the impression of less horizontal expressions.

#### *I believe that intact nature is not the target, or the main problem, but heavily exploiting without clear management plans.*

We agree with the reviewer - the heavy exploitation (and in general heavy impact) are main problems, and we refer to that in different ways throughout the manuscript, and this is also a main reason behind the manuscript as such. The first three sentences in the Background section are underlining both our dependence of nature and our impact on nature. The reviewer points at lines 53-54 (now l. 51-52). We hope that our revision of this sentence makes it clearer: "A well-functioning nature is dependent on healthy ecosystems, which again is intimately linked with biodiversity."

#### *L. 78: I understand what the authors wish to say, but my feelings is that the phrases "by being aware of it" and "impossible to take care of things we do not know" need to be rephrased.*

These two sentences (now l. 74-79) were attempts to summarise and simplify complex and diversified topics. We have now revised the mentioned sentences to: "With the strong influence that humans have on the ecosystems and the Earth, we will only be able to maintain the diversity and exploit it in a sustainable way by having relevant knowledge about the diversity. It is difficult or impossible to take unknown or undetected species into considerations in a management plan, or to make proper management plans for species, an ecosystem, or a geographical area when relevant and significant biological knowledge is not available."

#### *L. 90 (now l. 91): Needs to be rephrased.*

We suppose the reviewer is thinking of the formulation "seriously entered the stage". We thought this was good description of what happened - you barely find the terms "sustainability" and "biodiversity" used in international policy before 1987, but after 1987 the terms have been much used. We have now revised the sentence to: "In international policy, the terms "sustainability" and "biodiversity" became much more frequently used after..."

#### *L. 196 (now l. 201): Maybe replace moral with ethical?*

We were thinking of moral as the implementation of ethics. We believe that many nations are "good" with regard to words and thinking ("ethics"), while fewer nations really achieve their aims by the implementation of their thinking ("moral"). With this formulation we want to say that more actions (and less additional words) are needed by many nations. We also use the same expression in the Abstract (l. 42-43). We also use "moral" at l. 161. We prefer to keep the formulation unaltered.

*Regarding structure I have the following comments...*

We have made considerable rewriting and restructuring of the two sections "Biodiversity and conservation" and "Sustainability and commercial exploitation" (too many to be listed here). We have kept the section titles, as we feel that they are important in the structure, indicating the main focus area in each of the two sections.

*L. 371. ...the contribution of Faroe Island ERGA pilot is not clearly explained... It is important to show why each species was selected and what avenues this opens for future management.*

Quite some restructuring and other revisions have been done in the two paragraphs concerning *Ammodytes marinus* and *Argentina silus* (lines 336-372 in original manuscript; now lines 337-385). To make it clearer that *Ammodytes marinus* and *Argentina silus* are Faroese ERGA pilot species we have added "Faroese" to the information that these are ERGA Pilot species. We have also added some new pieces of information, including that we also are sequencing the lesser silver smelt (*Argentina sphyraena*), and we have added a figure showing the two *Argentina* species. We hope the revisions make it more clear we have selected these species because (i) both species are commercially exploited, (ii) we have little knowledge on their population structures (which include genetic diversity and gene flow between different geographical areas), (iii) both have very similar species within their geographic distribution (as an illustration, we have now included a Figure showing the similarity between *Argentina silus* and *A. sphyraena*), and (iv) in particular the sandeels are of known ecological importance in marine food webs. For both species, the knowledge obtained through our project will contribute to a better basis for management and decisions of quotas.

*L. 379 (now l. 396). Reference genomes are amazing tools, when coupled with population genomics data. Not the genome alone.*

We fully agree with the reviewer, and that is why the last part of the original sentence stated: "...and it can later be diversified into separate and specialised sub-tools for specific questions and investigations." To avoid any potential misunderstandings, we have simplified the first part of the sentence using the term "basis" ("High-quality genome assemblies are likely *the* best basis for acquiring such knowledge..."). We also mention population genetics throughout the manuscript, and it was (and is) specifically mentioned as the second main aim for our local project Gen@FarE both in the Abstract and in the main text.

*I really enjoyed reading the "Incidental insights" paragraph and think it fits better as the last paragraph of this paper.*

Moved as suggested by the reviewer.

## **Reviewer 2:**

*...the first half of the introduction is quite manifest-like and could be made more concise...*

We can see the reviewer's point, but, admittedly, parts of the manuscript are written with the thought that this paper (if it should be accepted) could be used locally in the context of administrations and politicians. That is why we repeatedly refer to CBD because it is one of the few international agreements concerning nature that the Faroe Islands have joined. We have now also added sentences and/or references to UN Agenda 2030 and UN Sustainability Development Goals (lines 98-100, 292-295), and (non)membership in EU (lines 101-102).

*L. 70->; L.195->; L294 etc: Mapping of genetic diversity is important, however I would like to know more what the authors mean by "establishing population genetics for all commercial species". What are these*

*species and what would be sufficient sampling to achieve sufficient coverage? How does this work for the oceanic fish stocks whose population encompasses the whole Northern Atlantic?*

We are somewhat surprised by this comment and these questions. We have a quite classic understanding of population genetics. It can be used for investigating many questions, including the potential existence of separate stocks (independently breeding subpopulations) in a species. There are no inherent principal problems for fish (or other species) that have a population that encompasses the whole North Atlantic. The major practical problem is that we ideally would like to have samples from spawning individuals in the different geographical locations, which is not always easy. There are also other practical problems, like efforts, costs and transport of samples across national borders. We have already sequenced the Atlantic herring (ref. 52 in original manuscript, now ref. 57) and made population genetics on Northeast Atlantic herring stocks (ref. 54 in original manuscript, now ref 59). We are presently doing that also for the greater silver smelt (lines 369-371 in original manuscript, now 350-353) and lesser sandeel (lines 347-353 in original manuscript, now 372-375).

We are not sure whether the reviewer wants a listing of commercially relevant marine species in the manuscript. As of today, there are probably around 30 species that are commercially exploited in Faroese waters, but if we include bycatches and potential future exploitations, the list will be longer. However, our first aim is to obtain high quality genome assemblies of all Faroese species, not only the commercial ones. For example, of the around 50 bird species commonly breeding on the Faroe Islands, chromosome level assemblies already exist for 14 species, and one of them was even sampled in Faroe Islands (whimbrel; GenBank GCA\_030770645) without our involvement.

*L. 195 (now l. 201): Not a single whale species is mentioned in this chapter?*

True. It is not the purpose of this paper or this section to make an extensive overview for all kinds of organisms - these are just a few examples. It has not been made any attempt to cover all groups and the whole biodiversity. There are lots of other large groups of organisms that we do not mention (insects and non-insect arthropods, fungi and mushrooms, plants, amoebas and other single-celled eukaryotes, etc.). With his/her comment, we suppose the reviewer is thinking along the same lines as mentioned for the comment to l. 294 (below). With regard to the whale and dolphin species that are associated to Faroese whale hunting (see also comment to l. 294), we may add that:

(i) the long-finned pilot whale is not considered threatened (IUCN: Least concern, <https://www.iucnredlist.org/species/9250/50356171>);

(ii) NAMMCO has estimated the Northeast Atlantic population to be 380 000 (2015) and the Global Biodiversity Information Facility (GBIF) (<https://www.gbif.org/species/2440596>) mentions a North-Atlantic population of 780 000; and

(iii) the Faroe Islands/Greenland outtake on annual average is less than 0.2% of the NAMMCO-estimated Northeast Atlantic population. GBIF states: "*Despite this catch rate, the Faroe Islands fishery is considered to be sustainable.*"

For dolphins (which generally are a bycatch), the most common caught species is Atlantic white-sided dolphin (abundant, no population estimate, least concern on Global Red List) and common bottlenose dolphin (least concern on Global Red List, population at least 600 000). The recent ICES report (the newly added ref. 54) states on p. 18 "*Current threats to marine mammals in the Faroes ecoregion are low and related to the potential risk of incidental bycatch and noise associated with fishing together with contaminants accumulated from global sources.*"

*L. 216 (now l. 218): The runs of homozygosity do not correlate with Red List status. It is fairly easy to think of examples (including our own species), which shows little variation but have huge populations...*

We fully agree with the reviewer. We are well aware that ROH remain in an expanding population after a bottleneck, while new variants are slowly accumulating. The reviewer's example describes a situation that is similar to the situation covered in refs. 27-29, and we have now expanded this sentence with "as they are recognizable long after a potential expansion of the population following a bottleneck" (lines 218-219) and added another reference about Red List and loss of heterozygosity (ref. 30). Our text was (and is) more focussed on shortly discussing the accumulation of ROH during the population declines and population lows (i.e., the situation just before and into a potential bottleneck), and why ROH does not necessarily correlate with Red List status. In other words, we are hinting at that the dynamics of the decline and the population size must be considered together if loss of heterozygosity and accumulation of ROH should be included as a parameter for Red List inclusion.

*Generally, I would like the authors to discuss more the practicalities for their proposals. For example, what resources (money personnel or infrastructure) does genetic/genomic sampling require to be effective? What organism groups the citizen science projects can successfully target in the Faroese context?*

In our view, the topic that the reviewer raises here is outside our intended scope of this manuscript. There are too many factors and parameters that can influence the total costs. For example, there is no estimate over the total number of eukaryotic species in the Faroe Islands (one of the reasons for the third aim for Gen@FarE). Additionally, as already mentioned in the manuscript, there are few Faroese species that are endemic to the Faroe Islands, and thus a Faroese species might become sequenced by foreign groups without our involvement (exemplified in our answer to the comment L. 70->; L.195->; L. 294).

But we may give the reviewer an impression of the cost - if the sequencing and population genetics of Faroese species should only be financed from the Faroe Islands. Our project on the two ERGA Pilot species, the lesser sandeel and the greater silver smelt, has an estimated total cost of >5 million DKK. This includes the generation of the reference genomes and population genetics in the Northeast Atlantic. As a comparison, the total annual research budget for the Faroese Research Council (the main national funding of research) has for many years been between 7 and 8 million DKK. Thus, in national context, there are substantial (potential) costs involved. Being rather pragmatic (but not without visions), we prefer to plan our work step by step according to the financing we are able to acquire. Additionally, we will of course utilise relevant genomes that have been assembled in other projects, and we will gladly join population genetic projects initiated and financed from elsewhere.

Taken together, we think it is a futile exercise attempting to calculate the financial resources needed to be effective. And in any case, it is not the sampling for a reference genome that is the most difficult, expensive or time-consuming part. Furthermore, we believe it is important to start using the genome assemblies for the benefit of biodiversity and society as fast as possible, and for this purpose population genetics and eDNA are powerful tools.

At this point, the reviewer mentions citizen science. We may get the impression that the reviewer is here thinking of using citizen scientists to collect samples for genome sequencing. We are presently not pursuing this line, as sampling capacity is presently not a bottleneck. When citizen science is mentioned in this manuscript, it is for observations, with the aims of mapping distribution, abundance, migrations, etc., and not for genomic sampling. There are many groups of organisms that can be suitable as targets for observational citizen science: Birds, plants, lichens, insects, mushrooms, fishes, brown and red macroalgae, other organisms living in near-shore shallow waters, etc.

L. 243 (now l. 250): Oxford Nanopores -> Oxford Nanopore Technologies.  
Done.

L. 294 (now l. 288): How about grindadrap or pilot whale/dolphin hunting? ...cryptic species...

We are well aware that the traditional Faroese pilot whale hunting is internationally controversial. However, the Faroese whale hunting is not commercial (at least not in any common sense of the word), and this section focuses on species of commercial interest. There are far better arguments against pilot whale hunting than sustainability and conservation, but we feel that a discussion on whale hunting would be a sidetrack for the present manuscript. See also our comments above to l. 195.

To the best of our knowledge, none of the genetic investigations performed on long-finned pilot whale have yet suggested the presence of cryptic species, but of course, this cannot be fully excluded before many individuals of each (assumed) species have had their genomes assembled.

L. 424 (now l. 456): Curiously, the Faroese hare seem to be grey in the winter, which would be nice to mention as an adaptation?

The fur colour of Faroese hare is under active investigation in another project. As now stated in the text, a similar grey fur is expressed in certain parts of Norway (locally known as "Jærhare" or "blåhare" (blue hare)), and it is likely that the allele was present in the initial four animals imported. We have now added three sentences about the winter fur (lines 456-463).

L. 452 (now section starting at l. 466): Are there any shortcomings of citizen science initiatives (frequent misidentifications, observations capturing mainly common or charismatic species)? Are there any ways to improve these by targeted campaigns and expert help? What resources would be needed?

Yes, the reviewer is absolutely right about potential shortcomings of citizen science registrations, including those that are mentioned by the reviewer. And yes, there are absolutely different ways to counteract such shortcomings. Of course, the overall quality of citizen science data are generally expected to be somewhat lower than similar data collected only by professionals (ref. 97), but the amount of data will be much greater than would be otherwise possible to collect. We have now included four references that discuss the quality of citizen science data and ways to counteract the inherent lower quality compared with professional-only data (refs. 98-101). We feel that a more detailed discussion on this topic is outside the scope of the present manuscript.

#### **Other comments**

We have added references to UN Agenda 2030 (line 99-101; refs. 9, 10), and mentioned that the Faroe Islands are not EU member, despite that Denmark is a member (lines 101-102).

We have added a reference stating that fisheries are the main threat to the Faroese marine ecosystem according to a new report from ICES (ref. 54, lines 295-296).

We have added a sentence referring to UN Sustainability Development Goal 14 Life Below Water (lines 293-295).

We have added a sentence referring to Kunming-Montreal target 6 about invasive species (line 430-432). In that context, we have also added two sentences stating that rats and mice are present in the Faroe Islands as invasive species (lines 430-435).