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Interactive comment on "Bio-geographic classification of the Caspian Sea" *by* F. Fendereski et al.

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Dear Reviewer,

We are deeply indebted to Reviewer 2, Tamara Shiganova, for her instructive comments and suggestions on our manuscript, and for the indication of many useful references on marine ecosystem structure, species distribution and invasive species in the Caspian Sea.

In her review, Prof. Shiganova highlights the need for comprehensive data set of species presence-absence across several trophic levels (phytoplankton to fish) for the comprehensive validation of our bio-geographic classification of the Caspian Sea using biophysical data. For a full-blown biological validation of our ecoregions, data synthe-

sis of observations of several 100s if not 1000s of plankton and fish species would be required. The data would require gridding, mapping and extrapolation of scarce biological data to the entire Caspian Sea using techniques of, for example, species distribution modeling (e.g. Irwin et al. 2012). Such a data collection effort has been recently made for the globe for plankton functional types only, and took several years to complete (Buitenhuis et al. 2013), with modeled habitat maps only becoming available now (e.g. Brun et al., submitted). While an extensive data synthesis is a major priority of our future research, clearly, such an extensive validation of our ecoregions is beyond the scope of the present manuscript. The data we have used is the only data set available where species data for a large set of species has been gridded and extrapolated to the entire area of the Caspian Sea, i.e. the only data set for which presence-absence information as given in the available habitat or distribution maps is available for all ecoregions, i.e. the entire Caspian Sea.

In the revision of our manuscript, we had the choice between a complete removal of the current biological validation of our ecoregions due to the lack of such a comprehensive data set comprised of 1000s of species, or to keep the current validation, along with a thorough revision of the methods section where this data is introduced, and the discussion of the implication of the validation and the caveats of the data set used. We have chosen to follow the latter strategy, i.e. to keep the biological validation of our ecoregions in the revised version of the manuscript, because we think such a validation is essential for any biophysical classification that claims to be of relevance for ecosystem structure, and also because differences in ecosystem structure are already evident from an examination of the few species for which distribution maps for the entire Caspian Sea are available. Furthermore, as the marine ecosystem in the Caspian Sea is changing at a high rate due to the interplay between environmental conditions, and the interaction of invasive species with the native flora and fauna, all available tools that could assist large-scale monitoring and ecosystem management of the Caspian Sea should be explored. If a link was detected between environmental conditions on the biome scale and species community composition (both taking into account native and

invasive species), monitoring of the ecological status of the Caspian Sea using remote sensing techniques at high spatio-temporal resolution could be essential for ecosystem management. Last but not least, reviewer 1 highlighted the importance of the biological validation of our biophysical classification as one of the "main assets of the study", further supporting its inclusion in this paper. However, we have thoroughly revised the methods, discussions and conclusions sections in order to 1) revise the taxonomy and exclude species that are no longer present in the Caspian Sea, 2) clarify the purpose of the validation we have done in the introduction section, 3) highlight the caveats of the data sets more clearly in the methods and discussion section, refer to the publication of Shiganova et al. for further information on the Caspian Sea species distribution patterns in the introduction section, and 4) discuss the urgent need for a comprehensive multi-species data synthesis for the Caspian Sea species for monitoring and conservation purposes in our discussion section. As our validation shows clear differences in ecosystem structure between ecoregions, we believe that the latter strategy is our best alternative given the current data availability, and hope to be an active part of an extensive data acquisition effort in the future.

Below is our response to the Reviewer 2's comments:

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RC1: It could be more accurate to subdivide also eastern and western Southern basins, they are very different in accordance to annual mean SST.

Response to RC1: The current map of the Caspian Sea ecoregions has been generated based on an objective classification using a self-organizing network. Thus, divisions were based on similarity criteria between environmental variables, and the optimal number of ecoregions has been determined using a cut off of the HAC dendrogram for 11 ecoregions that led to the lowest total error in a cross-validation (with further unifying two ecoregions in the NCB). In our procedure, which we believe is the optimal objective method according to our knowledge to date, the eastern and western

Southern basins did not emerge as different ecoregions. This is likely due to the fact that the presented subdivision is based on the influence of six independent variables simultaneously and not solitary on SST data. Furthermore, an apparent similarity in the environmental conditions of the western and eastern parts of the SCB has been demonstrated by Hosseini et al. due to a cyclonic current in the area (Hosseini et al., 1996). Thus, we believe that the combination of the eastern and western Southern basin region, an emergent feature of our method, is fully justified.

RC2: Authors used rather old and not reliable source of biological parameters as target species selection.

Response to RC2: For the validation of our bio-geophysical classification, we have performed an extensive literature research on the Caspian Sea biology and species distribution. Unfortunately, the Caspian Sea lacks a comprehensive up-to-date species data set that contains species distribution maps for more than one species, with species distributions determined for the entire Caspian Sea area and not only selected regions. Unfortunately, the available data are sparse and not evenly distributed throughout the whole Caspian Sea, i.e., the domain of our study. To our knowledge, the current data set provided by the Caspian Environment program, although not the best possible but the best available, is the only source where multiple species have been mapped for the whole Caspian Sea. As mentioned in our general reply above, a comprehensive metadata analysis and data synthesis for all biological data that has ever been recorded in the Caspian Sea, the gridding of the data and the extrapolation onto the biome scale would be a much needed future project, but such a data synthesis is far beyond the scope of the current manuscript. In the revised manuscript, we have highlighted the deficiency of the currently used data in the methods section (page 7, lines 27-32) and as a caveat for our work in the discussion section, page 24, lines 17 to 23. We further highlight more clearly that the presented species validation of our ecoregions is just a starting point and more emphasis needs to be put on this part of the work with major contributions from all countries bordering the Caspian Sea (methods, page 8, lines 17-

19 and discussion, page 22, lines 26-28 and lines 30-31, page 23, lines 1-2 and page 24, lines 22-26). We recommend a comprehensive meta-data analysis for the Caspian Sea environment as a next step for the understanding of the Caspian Sea environment in the discussion section (page 24, lines 24-32 and page 25, lines 1-9), and highlight the large consequences of changes in ecosystem structure in the Caspian Sea due to the invasion of many non-native species, as highlighted by Prof. Shiganova (page 3, lines 11-22 and page 24, lines 18-22).

RC3: Phytoplankton is presented only one species Rhizosolenia fragilissima. First it is an old Latin name, now it is Dactyliosolen fragilissimus (Bergon) Hasle, 1996 (WoRMS). This species was abundant together with another diatom Prorocentrum cordatum (=Exuviella cordata). But it was replaced by non-native species Pseudosolenia calcar-avisÂň, which is now the most abundant and widely distributed around the Caspian, along withtwo other non-native phytoplankton species Pseudo-nitzschia seriata and Cerataulina pelagica (Shiganova et al., 2005; Shiganova, 2012).

Response to RC3: We have changed the name of the species Rhizosolenia fragilissima to the new one, Dactyliosolen fragilissimus, and thank the reviewer for pointing out this change in taxonomic denomination. According to the suggestion of the reviewer, and considering the distribution of D. fragilissimus in the Caspian Sea, which is largely under the influence of top-down controls since 1930s (Karpinsky et al., 2010), we have now removed this species from our analysis in the revised version of this manuscript (page 8, lines 12-16). Also, in the introduction and discussion sections, we now highlight that other species have been recorded for the Caspian Sea, but that an extensive meta-data analysis would be required in order to generate habitat maps for all dominant species currently established in the entire Caspian Sea (page 5, lines 3-19). We further stress that such a data collection must urgently take into account recent changes in the Caspian Sea marine ecosystem structure and composition due to invasive species. We state this as one of the main priorities for future work in the discussion section (page 24, lines 18-28).

RC4: Zooplankton is represented copepod Eurythemora grimii and invasive ctenophore Mnemiopsis leidyi. Why did authors select only Eurythemora grimii? Certainly it is wide distributed species and had to be selected but why did not take another widely distributed abundant copepod Calanipeda aquae-dulcis. After invasion of Mnemiopsis leidyi both species replaced by non-native species Acartia tonsa, which during summer comprised up to 95% zooplankton (Shiganova et al., 2004; 2012).

Response to RC4: Again, due to the lack of comprehensive zooplankton data, we inevitably confined our validation to these two species. As Prof. Shiganova highlights, E. grimii is a widely distributed species. The reported decrease inÂň the abundance of this zooplankton after the jellyfish invasion in 2001 has been attributed to biological, and not physical, changes in the Caspian Sea (Roohi et al., 2010). Thus, considering the date of E. grimii distribution data, which predates the jellyfish invasion, and in agreement with the view of the reviewer, we have decided to keep this species in our set. A distribution map of Acartia tonsa was also available in caspianenvironment website, but the data was unfortunately limited to the MCB and some parts of the NCB. No sampling data has been provided for the SCB. This is why we have excluded A. tonsa from our study. We revised the methods section on the selection of species data included here, and explained which species had to be removed from our analysis due to the lack of representative data in all ecoregions of the Caspian Sea (page 8, lines 6-12).

RC5: Marine fish species Liza aurata and Liza saliens occur mainly in the southern Caspian. Clupeonella cultriventris caspia it is now Clupeonella cultriventris. Genetic analysis has shown that the Black and the Caspian species are the same species (Stolbutova, Slynko, 2005).

Response to RC5: The non-native species, Liza aurata and Liza saliens, are thermophilic warm water species that distributed in the Middle and Southern Caspian basins. Only single specimens of these two species occur in the NCB. The absence of thermophilic species in the cold ecoregions of the NCB is exactly what our valida-

tion test was looking for, i.e., the link between spatial variability in physical conditions and species distribution patterns in the Caspian Sea. We changed the name Âňof Clupeonella cultriventis caspia with Clupeonella cultriventris and thank the reviewer for pointing out this change in taxonomic denomination.

RC6: Pontastacus eichwaldi occurs now very rare and it is included in Red book.

Response to RC6: Although our ecoregions have been derived from data that span the last decade, however, as we were unable to retrieve information on the exact year when a drastic decline has been reported for this arthropod in the Caspian Sea, based on Prof. Shiganova's suggestion, we exclude this species now from our biological validation test. We now highlight that the marine ecosystem has been changing drastically in the Caspian Sea, especially due to the spreading of invasive species in our introduction and discussion sections (page 3, lines 15-22, page 5, lines 3-19 and page 24, lines 19-26), and the importance of a comprehensive data synthesis effort for this region.

RC7: In benthos it had to be included Hediste (Nereis) diversicolor intentionally introduced species which widely distributed around the Caspian now (Karpinsky et al., 2005).

Response to RC7: We agree that a comprehensive data synthesis of biological observations in the Caspian Sea would be of tantamount importance, and that this classification must include newly introduced benthos species such as Hediste (Nereis) diversicolor in different ecoregions. Yet, at the moment, a distribution map of N. diversicolor is not available for the whole Caspian Sea.

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C4544/2014/bgd-11-C4544-2014-supplement.pdf

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