An ecological analysis of rockfish assemblages along environmental gradients

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Abstract:
Four distinct assemblages of continental shelf and slope rockfish species are described for Alaska based on ecological similarities with environmental variables. These assemblages are defined by the distributions of species along gradients of depth and location and, to a lesser extent by temperature. The 180 km depth contour was a major division between an assemblage inhabiting mid-depths on the upper slope and shelf and a deeper assemblage on the lower continental slope. In addition to the depth division, another noticeable transition was between species centered in SE Alaska and those found in the northern Gulf of Alaska and the Aleutian Islands. The distribution of species over environmental gradients was correlated to their frequency of occurrence in trawl catches, indicating those species with similar environmental preferences were more likely to be captured together. The method of defining rockfish assemblages by determining the distributions of such species group along environmental gradients and examining the potential overlap among species is different than commonly utilized methods that cluster trawl survey catches or sites with similar catch constituents. However, the method used here provided results similar to other studies and, because it is based on an ecological framework, it may be more robust for prediction and management purposes.

Introduction:
Existing management of marine fish species requires all ecosystem components to be accounted for in the management framework. Thus, it is important to know the major environmental gradients along which species are organized in marine systems. The theoretical distribution of a single species across an environmental gradient can be approximated by a normal distribution. Ecological theory predicts that every species will inhabit a natural niche of environmental conditions in the face of existing competition and that two coexisting species cannot occupy the same niche. Using these principles in an ecologically based approach should improve our ability to define species assemblages with similar habitat requirements and thus similar responses to environmental changes, such as global warming.

OBJECTIVES:
1. Examine the distribution of rockfish species across the Gulf of Alaska (GOA) and Aleutian Islands (AI) in relation to environmental variables.
2. Test for species overlap and detect assemblages of the life history stages and sexes of rockfish that share similar distributions across environmental variables.

Methods:

BIOLOGICAL DATA: CPUE of rockfish from bottom trawl surveys in GOA & AI, 1990-2005

SPECIES GROUPINGS: by species, juvenile, adult, male, female

ENVIRONMENTAL VARIABLES:
Depth, Temperature, Location along coastline

ANALYSIS:
1. Calculated niche dimensions (CPUE weighted mean and SD) along the three environmental variables for each species-grouping using methods of Murawski and Finn (1988; Fig. 2).
2. Calculated overlap index for each pair of species-groupings (groups within a species were combined if overlap > 0.95).
3. Compared combined overlap indices among pairs of remaining species, sizes, and sex groupings.
4. Clustered combined overlap indices of species-groupings to find those species groups with similar distributions across environmental gradients.

Results and Discussion:

SPATIAL DISTRIBUTION RELATIVE TO ENVIRONMENTAL VARIABLES:

• No separation between sexes (except for black rockfish; Table 1).

• Seven species groupings were used in the cluster analysis (Table 1).

• There were three isolated species, juvenile black rockfish, quillback rockfish & longspine thornyhead (Fig. 4).

• There were four clusters of the remaining species groups (Fig. 4):
  i. A mid-water assemblage centered in the Aleutian Islands (Mid-AI).
  ii. A deep-water assemblage in the Aleutian Islands (Deep-AI).
  iii. A mid-water assemblage in SE Alaska (Mid-SE).

ASSEMBLAGES:
ASSEMBLAGES (continued):

• No separation between sexes (except for black rockfish; Table 1).

• Assemblages had different distributions across the depth and location variables, with less separation around the temperature variable (Fig. 3).

• The method presented here is different from traditional statistical methods of assemblage analysis (PCA, MDS, etc.).

Recommendations on the "Future of Fishery Science":
- Mechanistic models derived from ecological principles are generally better than correlations.

- Environmentally-based assemblages, such as those presented here should allow prediction of changes in rockfish community structure with climate change or oceanographic events. For example, a shift in the distribution of sharpchin rockfish with predicted global warming may be expected to expose them to competition with adult POP for prey resources in the north Gulf of Alaska and Aleutian Islands regions.

- Spatial management should move towards meaningful ecological boundaries for fish stocks. The boundary between the Aleutian Island and Gulf of Alaska ecosystems (and management boundaries fitting boundary would separate southeast Alaska from the rest of the Gulf of Alaska and Aleutian Islands. Additionally, based on these assemblage analyses, marine protected areas could be designed for specific depth and geographical areas that would protect portions of rockfish populations.

- Fishery independent surveys should be tailored to match the species of interest. Current trawl surveys in the Gulf of Alaska and Aleutian Islands do not account for the ecological divisions among rockfish assemblages or ontogenetic shifts in species distributions. For example, the most important commercial rockfish in Alaska is Pacific ocean perch. Based on the analysis presented here, a trawl survey encompassing the Gulf of Alaska and Aleutian Islands with depths from 67 to 337 m would assess 90% of the realized niche of adult POP.

- Alternative assessment methods are needed. Much of the variability in catches of some rockfish species, such as southern rockfish, is because of their predation on unpalatable areas. Non-extractive methods to assess rockfish throughout all of their important habitats are needed.

Literature Cited and Acknowledgements:


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Fig. 1. Gulf of Alaska and Aleutian Islands ecosystems included in AFSC trawl surveys. Location is the distance of the survey from the Aleutian Islands (180 km depth contour is shown) and the distance to the right (offshore) and positive values are in the AI homeland.

Fig. 2. Gulf of Alaska and Aleutian Islands ecosystems included in AFSC trawl surveys. Location is the distance of the survey from the Aleutian Islands (180 km depth contour is shown) and the distance to the right (offshore) and positive values are in the AI homeland.

Fig. 3. Results of cluster analysis showing similarity amongst rockfish species subgroups. The x-axis is the relative similarity from multinomial overlap indices of species-group pairs along depth, location and temperature gradients.

Fig. 4. Results of cluster analysis showing similarity amongst rockfish species subgroups. The x-axis is the relative similarity from multinomial overlap indices of species-group pairs along depth, location and temperature gradients.