HCS170 - How habitat suitability does shape the 3D spatial organisation of anchovy across scales?

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Functional relationships in marine ecosystems are profoundly constrained by the spatial structuring of the physical landscape and by the way living organisms distribute themselves. The relative influence of these two determinisms is thought to depend on the spatiotemporal scale of the processes. Then, to improve our understanding of ecosystem functioning, we need to observe *in situ* the interactions between physical and biological features at different scales. For that purpose, the Peruvian anchovy (*Engraulis ringens*) is an interesting case study. This species supports the highest worldwide landings and is known to present very high population, distributional and even biological dynamics at different spatio-temporal scales (e.g. Bertrand *et al.*, 2004). Until now, most of the studies concerning this species focused on large and medium scale patterns (e.g. Chavez *et al.*, 2003). However, upwelling systems are spatially and temporally very heterogeneous, exhibiting a mosaic of nested dynamical physical structures at meso and sub-meso scales such as the frontal zones between coastal rich and oceanic poor water masses, plumes, filaments, eddies, internal solitary waves and other. Oceanographic and trophic conditions can therefore strongly differ from one place to another in a same zone and from one moment to another in a same place. In other words, anchovy habitat suitability varies according to the place, the scale of observation, the diel period, the oceanographic forcing or the predation pressure. In such context, the objective of this paper is to address the following questions: (i) how the physical environment forces organisms' distribution across scales? (ii) what is the relative importance of social vs. environmental forcing in the formation of fish 3D collective structures? (iii) how does the diel cycle structure and unstructure organisms' distribution and organisation?
For that, a specific behavioural ecology survey was performed in Central Peru, in November 2004. From a series of observation tools (SST and CO2 sensors, Niskin, CTD probes, zooplankton sampling, stomach content analysis, echo-sounder, multibeam sonar, birds and mammal observations) we assessed interactions between fish and the landscape features (both oceanographic and biotic) possibly driving its behaviour. Survey design consisted in 28 hours long series of square transects, 2 nmi large (1 nmi=1852 m), runs.
We could link levels of fish organisation (layer, school, shoal, cluster) to different oceanographic and biological features: upwelling area, plankton patches, solitary internal waves, predators and others, varying in space and in time, particularly according to the diel cycle. At a large scale (100s km), experiments took place in the core of anchovy distribution with abiotic factors ranging inside anchovy ecological niche. At a smaller scale, experiments were performed inside rich upwelling area corresponding to meso-scale oceanographic features (10s of km). The presence of a shallow oxycline limited the vertical range of anchovy and preventing any fish diel vertical migration. Plankton was very abundant and unevenly distributed. Where no specific sub-meso-scale features were present, plankton was distributed in 'classic' sound scattering layer. During the day, part of zooplankton migrated down and was less available to anchovy. Furthermore high predatory pressure by seabirds and sea lions also affected the habitat suitability. Anchovy was then distributed in schools with strong interactions with predators and a rather erratic horizontal distribution. During the night the upward migration of zooplankton associated with the lower predation pressure (no more seabird attack) increased the habitat suitability. Where no specific sub-meso-scale features were present, anchovy was distributed in loose shoals and scattered fish. Sub-meso-scales features (100s m – kms) had a strong impact on habitat suitability and anchovy 3D spatial distribution. Convergence lines concentrated plankton and locally deepened the oxycline, increasing the vertical range of habitat for anchovy. Plankton patches were observed during the night with anchovy concentrating inside. Anchovy cluster size was directly related to patch size. This argues in favour of a fish clustering related to the patchiness of the environment rather than to pure social behaviour or population aspects. Plankton patches were no more observed during the day. This does not mean that oceanographic feature responsible for patch formation changed but that plankton dispersed and migrated below the oxycline. A last aspect concerning these patches relates to the impact of plankton and fish concentration on the chemical characteristics of the habitat. Inside the patch, dissolved CO2 increased. We assume that this pattern is related to organism respiration. Therefore the suitability of these patches may decrease if 'too' many fish are concentrated in. To synthesise this complex panorama we adapted the basin model framework from MacCall (1990) to propose a conceptual model of environment impact on occupation of space by fish. We also propose a conceptual view of the relative contribution of behavioural vs. environmental process on the patterns of aggregation of anchovy according to the scales of observation.

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HCS186 - Ecological niche and patterns of distribution of munida (*Pleuroconodes monodon*) off Peru, and overlapping with anchovy (*Engraulis ringens*) between 1999 – 2006

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Regular monitoring of the distribution, abundance and catch of anchovy (*Engraulis ringens*) has been conducted over the last 50 years in Peru. These parameters vary over several time scales, in particular low frequency cycles of abundance (El Viejo, La Vieja), inter-annual variability (El Niño, La Niña) and seasonal variability. Although observations are not as extensive as for anchovy, the crustacean munida *Pleuroncodes monodon* (range of distribution 7°S - 43°S) is also an important component of the Peruvian ecosystem. Large amounts of munida were occasionally reported during the last 50 years, mainly in the southern part of Peru. Older reports indicate that munida was an important prey item of the diet of apex predators such as tunas during the 1930's and 1940's. Munida has become highly abundant along the Peruvian coast, since the 1997-1998 El Niño event. Acoustic estimates indicate that munida biomass ranged between 0.6 and 3.4 $x10^6$ t from 1998 to 2005. This large amount of munida is mostly restricted to coastal areas and has for a large impact on ecosystem function and trophic dynamics. Munida is now a very important prey for seabirds, mammals and coastal predatory fish including anchovy, that predates on munida's zoea. Also, munida can forage on eggs and larvae of fish, and thus be a predator of the early stages of some of its own predators. Despite its ecological importance, knowledge on munida patterns of distribution and ecological niche is scarce in Peru. Most published works on munida come from Chile where this organism is basically benthic (e.g. Gallardo et al., 1992). In contrast, munida is primarily pelagic in Peru

In this work, using a series of 22 acoustic surveys performed along the Peruvian coast from 1999 – 2006, we describe horizontal and vertical distributions of munida and associated ecological niche based on oceanographic parameters using spatial analyses and a generalized additive modelling (GAM) approach. As anchovy and munida were the two dominant small pelagic organisms during this period we also studied possible interactions between them and estimated the vertical and horizontal overlap between these two species.

Results indicate that munida distribution is strongly related to the cold coastal waters and ranges vertically between the oxycline and the surface. High horizontal overlapping exists between anchovy and munida (Fig. 1), although munida is more restricted to the coastal zone than anchovy. In the vertical plane, overlapping depends on the diel period. During daytime anchovy schools are distributed above the layer (or swarm) of munida with occasional overlapping. During the night anchovy and munida are dispersed and share the same vertical layer. The role of munida in the ecosystem is discussed with special consideration to potential competition for space, and food between anchovy and munida.

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