Influence of the hydrodynamic conditions on the accessibility of *Aristeus antennatus* and other demersal species to the deep water trawl fishery off the Balearic Islands (western Mediterranean)

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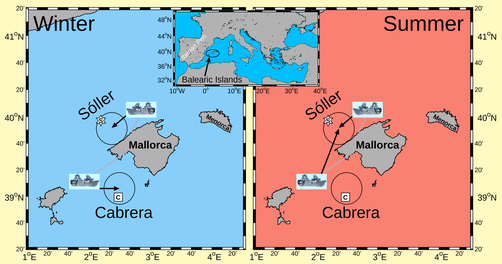
1.- Motivation



- Red shrimp (*Aristeus antennatus*) fished around Mallorca (Balearic Islands) is mainly caught in two different fishing grounds: Sóller (at north) and Cabrera (at south).
- During winter, the boats from Palma harbour fish in Cabrera and the boats from Sóller harbour in Sóller.
- During summer, the boats from both harbours fish in Sóller.
- **Why the fishing fleet from Palma harbour migrates every summer from Cabrera to Sóller fishing ground?**

2.- Available Data

Red Shrimp CPUE data:

- Daily time series of the landings from the bottom trawl fleet obtained from the official sale bills between 2000 and 2010 (both years included).
- No data from Cabrera is available from summer time.
- The red shrimp landings were transformed into monthly averaged CPUE time series, having only into account the adult individuals (carapace length ≥32mm), main target of the fishing fleet.

Satellite Images:

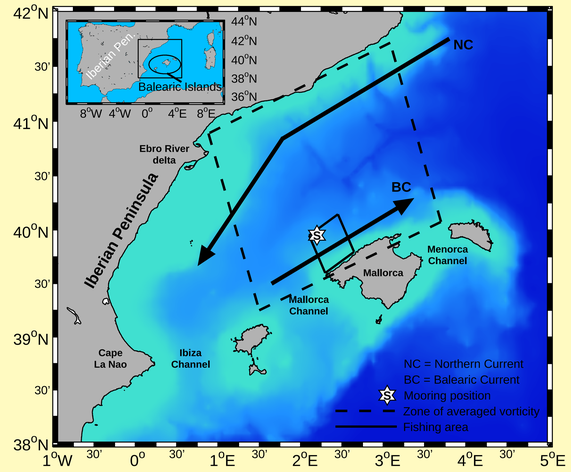
- We have estimated the relative vorticity ζ from the daily Sea Surface Height (SSH) satellite images (http://www.aviso.oceanobs.com) as:

$$\zeta = \frac{g}{f} \cdot \nabla^2 SSH \qquad (1)$$

- After computing the daily vorticity fields, we took the absolute value and computed the spatial average in the dashed rectangle represented in the figure from the right. Finally, the vorticity time series were monthly averaged.

Mooring data:

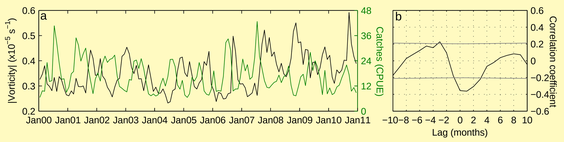
- A mooring were installed near each fishing ground. We have only used data from the mooring of this zone (star in the figure).
- The mooring, placed around 900m depth, had:
  - 4 CTD's SeaBird37 (300, 500, 700 and 900m; dt = 10 minutes).
  - 2 current meters Nortek Aquadopp (500 and 900m; dt = 30 minutes).
  - 1 sediment trap (30 meters above the bottom; dt = 10 days).



3.- Results

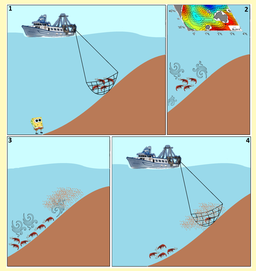
Correlations Vorticity Vs *A. antennatus* CPUE and suggested mechanism.

- Any increase in vorticity generally causes a decrease in the CPUEs, although a decrease in vorticity does not cause an increase in CPUEs (negative correlation):

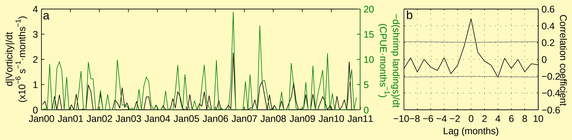


- The suggested mechanism explaining this correlation is shown in the figure below:

1. The *Aristeus antennatus* individuals are fished around 700 m depth.
2. Most of the eddies (important vorticity source) present in the zone would increase the near bottom velocity.
3. This near bottom velocity increase would create bottom turbidity. The red shrimp individuals would respond presumably moving toward higher depths...
4. ... where the fishing fleet is not able to catch them. The bottom turbidity would last some time after the disappearance of the eddy.



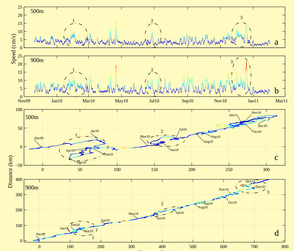
- As we want to **highlight** the part when the **vorticity increases** (positive derivative) and when de **CPUE decreases** (negative derivative) we have computed the derivatives of both time series and fixed to zero the negative vorticity and positive CPUE derivatives (also we have reversed the sign of the CPUE derivatives, next figure):



- The correlation has increased up to 0.48.

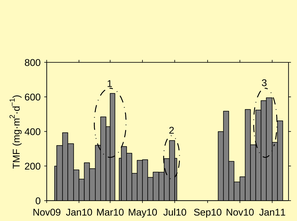
Explanation of the suggested mechanism.

- An increase in the absolute value of the surface vorticity is commonly caused by an eddy.
- During 2010, at least three eddies produced some footprint in the instruments deployed in the mooring line.

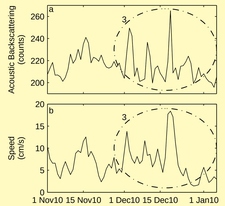


The two panels from above from the figure from right is a 24h low-pass filtered speed series of 500 and 900 m depth for the whole recorded period. The two panels from above are the corresponding progressive vector diagrams. The different colors coincide temporally with the speed time series. Enclosed areas represent moments where an eddy is present in the zone.

- The eddy number 3 was clearly reflected in the currents registered at 500 and 900 m depth by:
  - A significant velocity increase at both depths (spikes of 26 cm/s at 900 m depth).
  - Change of the current direction: complete reversal at 500 m and a down slope gyre at 900 m.
- This eddy reached the bottom, and the recorded gyres and velocity increases could easily have caused the material resuspension, hypothesis supported by three indirect measurements:



The increase in the total flux mass (TFM) recorded by the moored sediment trap at the time of the eddy.

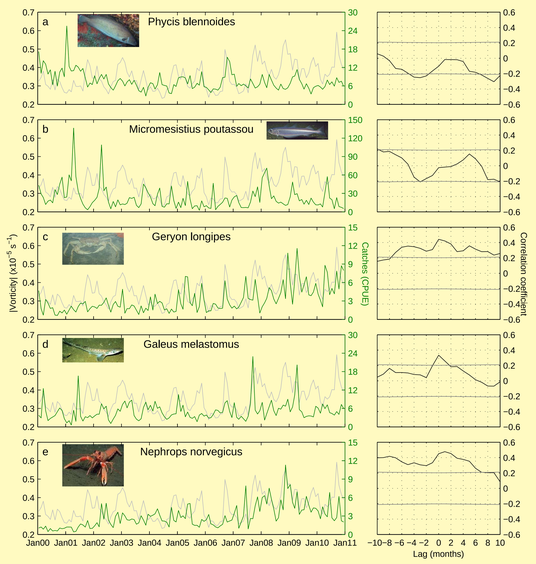


The increase of the acoustic backscattering during the episode coinciding with the speed increases.

The clear down slope gyre at 900 m which could be related to a near bottom turbidity current.

4.- Conclusions

- A reasonable good negative correlation was found between the monthly CPUE of the adult *A. antennatus* and the mean surface vorticity.
- Suggested mechanism:
  1. Eddies causing the vorticity events may reach the bottom, increasing the velocities.
  2. This effect would trigger the sediment resuspension and increase the bottom water turbidity.
  3. Such a change in the water conditions would force adult *A. antennatus* to move away from the fishing ground, probably downwards, to greater depths.
- The correlation found with other demersal species are consistent with the proposed mechanism:
  - The decapod crustaceans, *G. longipes* and *N. norvegicus*, the more sedentary and benthic species, show a significant positive correlation. These two species are closely connected to the bottom, as reflected by their feeding behavior and biological characteristics.
  - *G. melastomus*, which has more mobility, feeds on the mesopelagic preys with the occasional occurrence of benthic feeding activity and scavenging in the adult phase.
  - *M. poutassou* and *P. blennoides*, the two bentho-pelagic teleosts with greater capacity of movement above the bottom, are expected to be less affected by bottom water turbidity.
- **The answer to the motivation question why the fishing fleet from Palma harbour migrates every summer from Cabrera to SÃşller fishing ground? is perhaps obvious:**
  - **They follow the highest abundance of large red shrimp females in Sóller.**
  - **According to previous works, the vorticity episodes are much more intense off northern Mallorca during the winter time (October to March) than in Summer.**
  - **So, the absence of large adult aggregations in Sóller during the rest of the year (out of summer), probably related to the particular dynamics of the specie could be reinforced by a decrease in the availability of the red shrimp to fishing exploitation during these months when eddy episodes are more frequent in this area.**



5.- Future Work

As a future work, if we are able to estimate the time evolution of the vorticity in the Balearic Sea, throughout climatic models, we would be able to investigate how this changes could affect to the red shrimp CPUE's.

6.- Acknowledgments

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