Effects of climatic events on oceanic currents and connectivity

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Climatic anomalies have changed the ocean circulation pattern and thus the demographic connectivity. However, in many geographical regions there is insufficient evidence of this change. Therefore, in the Panama Bight, comparisons were made between neutral years and years of El Niño and La Niña with moderate intensity, for the North Equatorial Counter Current (NECC), the South Equatorial Current (SEC), the Coastal Current (CoaC) and the main anticyclonic eddy. Daily topography and wind stress data (1993-2007) were used to calculate surface speed currents from September to November (spawning time). The speed magnitude for the three oceanic currents was statistically different among the compared events, except for the anticyclonic eddy; and the number of eddies increased at El Niño conditions. In conclusion, anomalous climatic events alter the velocity of oceanic currents in the Panama Bight; consequently these could change the functional potential connectivity.

Marine currents are one of the mechanisms which promote passive transport of gametes, larvae among islands. Determining how the oceanic currents (velocity and direction), which changes seasonally (trade winds) and annually (inter-annual anomalies such as El Niño and La Niña events), affects the patterns of planktonic larval dispersal is important to understand demographic and evolutionary connectivity (Sale et al., 2010).

The Panama Bight is part of the Eastern Tropical Pacific Province (~1.2 106 km^2) and includes the marine corridor (CMAR, 2004) in which Ecuador (Galapagos), Colombia (Malpelo and Gorgona), Panama (Coiba), and Costa Rica (Cocos) implemented regional strategies for the preservation of marine biodiversity. The eco-region has three main oceanic currents and an anticyclonic eddy (Fig 1). Until now there is no evidence regarding the multiannual variability and effect of climate change in the velocity pattern of those currents during the spawning time (September to November).

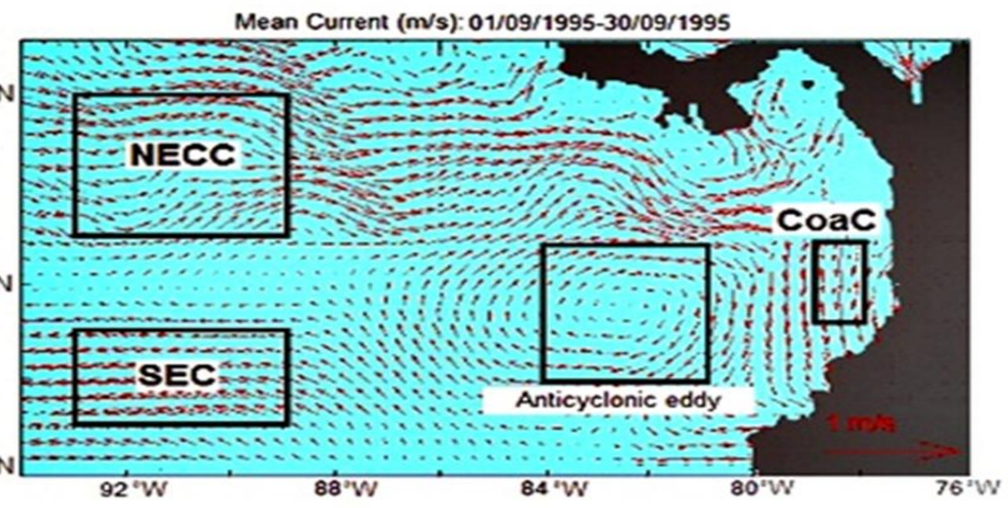

Figure 1. Oceanic circulation in the Panama Bight, major currents and eddy. NECC=North Equatorial Counter Current; SEC=South Equatorial Current; CoaC=Coastal Current.

The surface current velocity was obtained from both the dynamic topography data (MADT by AVISO; daily data, delayed time, 1/3° x 1/3° Mercator grid) and daily wind stress data (ECMWF-European Centre for Medium Range Weather, 6 hrs. temporal resolution and 0.5°spatial resolution - Lon/Lat).

Using the Oceanic Niño Index (ONI) we selected four years (1994, 2002, 2004 and 2006) with moderate El Niño (0.5 to 1.5 °C), three years (1995, 1998 and 2007) with moderate La Niña (-0.5 to -1.3°C), and four years (1993, 1996, 2001 and 2005) which were neutral (-0.4 to 0.4 °C). Then, the null hypothesis of no differences in current velocity was tested by comparing El Niño, La Niña, and neutral years (Table 1).

	Geographical Coordinates of the selected plot	Number of values per month	Number of values per quarter per year	Number of values per event (3 years-La Niña, 4 years-El Niño, and 4 for neutral years)
NECC	5°- 8°N, 89°- 93°W	140	420	Niña: 1260 Niño: 1680 Neutral: 1680
				TOTAL 4620
SEC	1°- 3°N, 89°- 93°W	98	294	Niña: 882 Niño: 1176 Neutral: 1176
				TOTAL 3234
CoaC	3°- 5°N, 78°-79°W	28	84	Niña: 252 Niño: 336 Neutral: 336
				TOTAL 924
Anticyclonic eddy	2°- 4°N, 81°- 83°W	36	108	Niña: 324 Niño: 432 Neutral: 432
				TOTAL 1188

Table 1. Selected plots where current velocity data were gathered for statistical comparisons (n=9966 vectors).

The speed magnitude for the three oceanic currents was statistically different among the compared events, except for the anticyclonic eddy.
NECC: Neutral > El Niño > La Niña (Kruskal-Wallis test, H2=188.61, n= 4620, p= 0.000; Fig. 2a).
SEC: La Niña > Neutral > El Niño (KW test, H2=1254.73, n= 3234, p= 0.000; Fig. 2b).
CoaC: La Niña ≈ Neutral > El Niño (KW test, H2=7.68, n= 924, p= 0.021; Fig. 2c).
Anticyclonic eddy: La Niña ≥ El Niño ≥ Neutral (KW test, H2=5.38, n= 1188, p= 0.067; Fig. 2d).

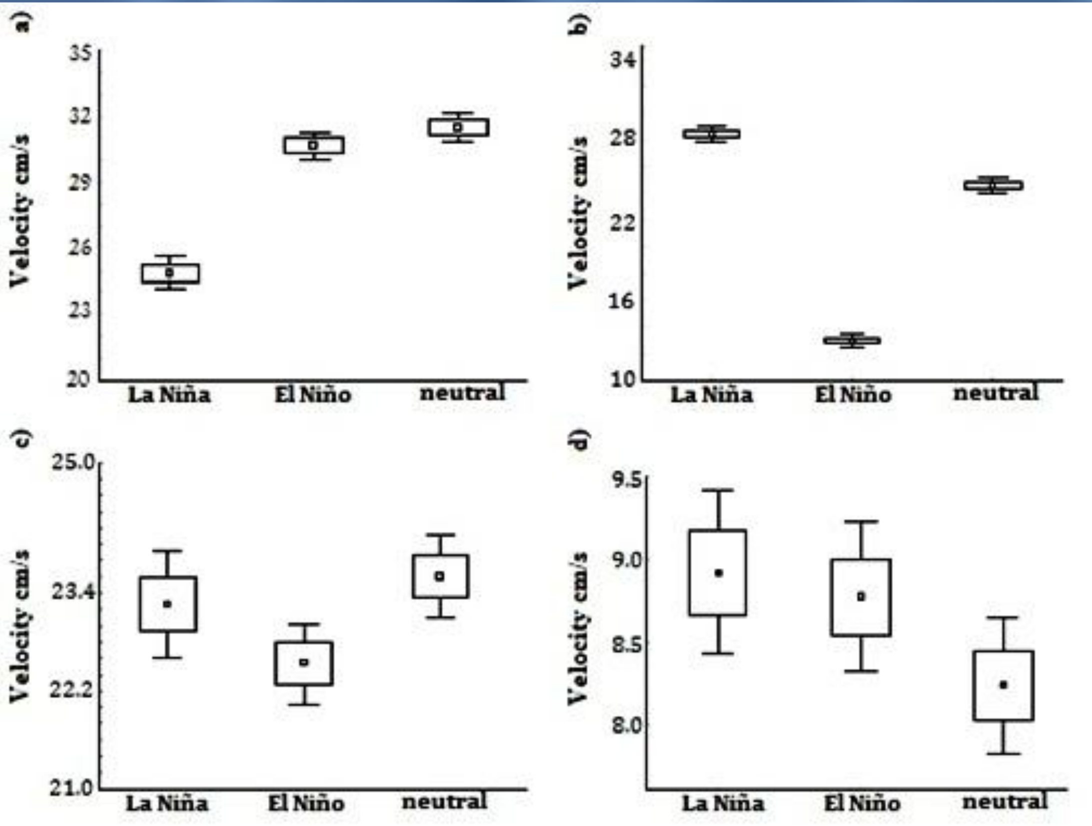

Figure 2. Comparison of the total average magnitude of the surface velocity between La Niña and El Niño events vs. Neutral years. The boxes represent the mean± standard error. a=NECC; b=SEC; c=CoaC; d=Anticyclonic eddy.

Direction of surface velocity

The NECC during Neutral and La Niña years was Eastward; at El Niño years it changed direction slightly, first towards the Southeast and later towards the Northeast, surrounding a cyclonic eddy at 7-9º N, 87-93º W (Fig. 3a). The SEC always flowing westward (Fig. 3b) and the CoaC southward (Fig. 3c). The main anticyclonic eddy was found at 2-4º N, 80-83º W for neutral years, moving westward during La Niña years (81-85º W) and El Niño years (81-83º W; Fig. 3d).

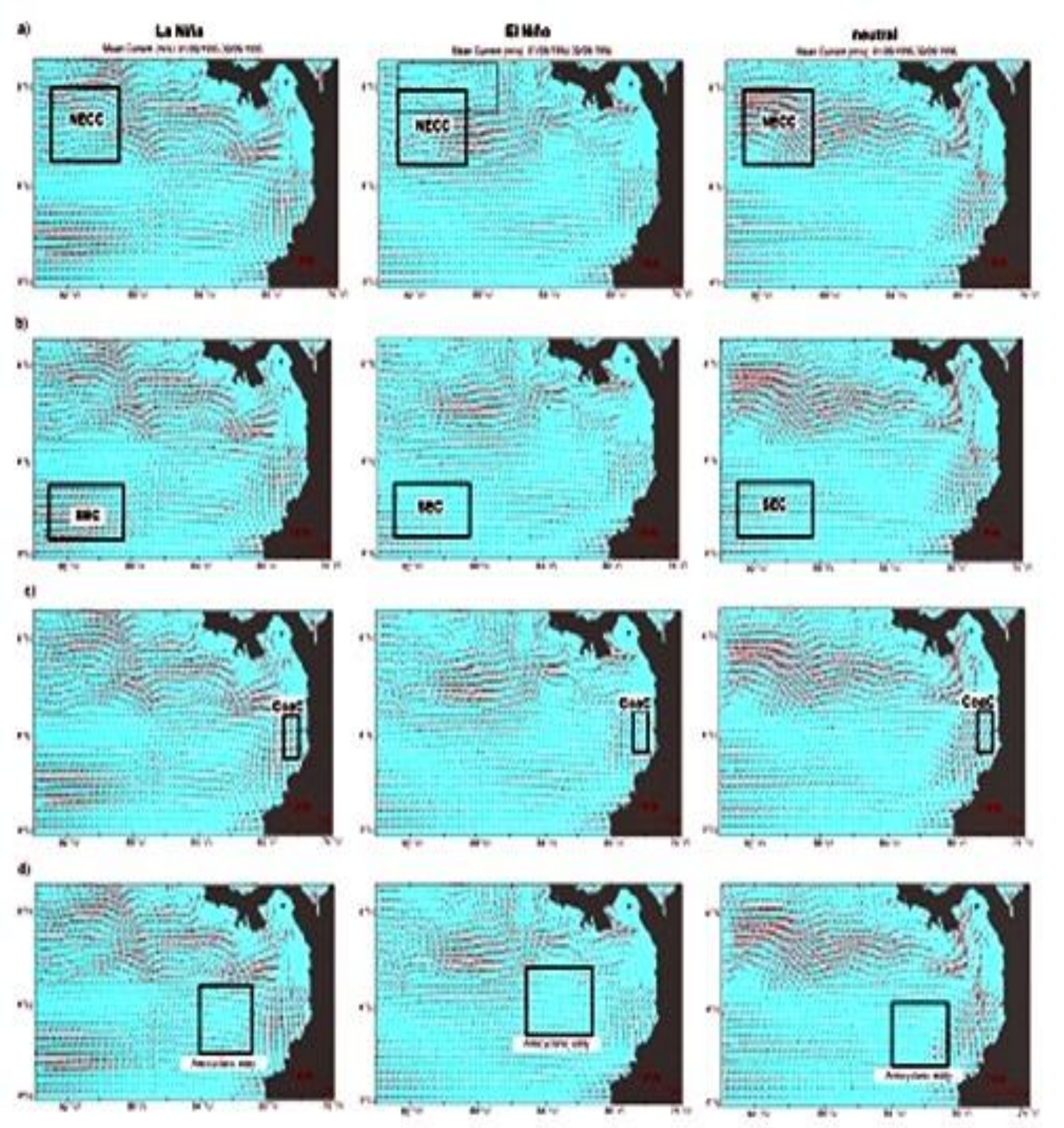

Figure 3. Direction of the main currents and the anticyclonic eddy. The results are represented as multi-year, quarterly average velocity figures per climatic event and per current. a=NECC; b=SEC; c=CoaC; d=Anticyclonic eddy.

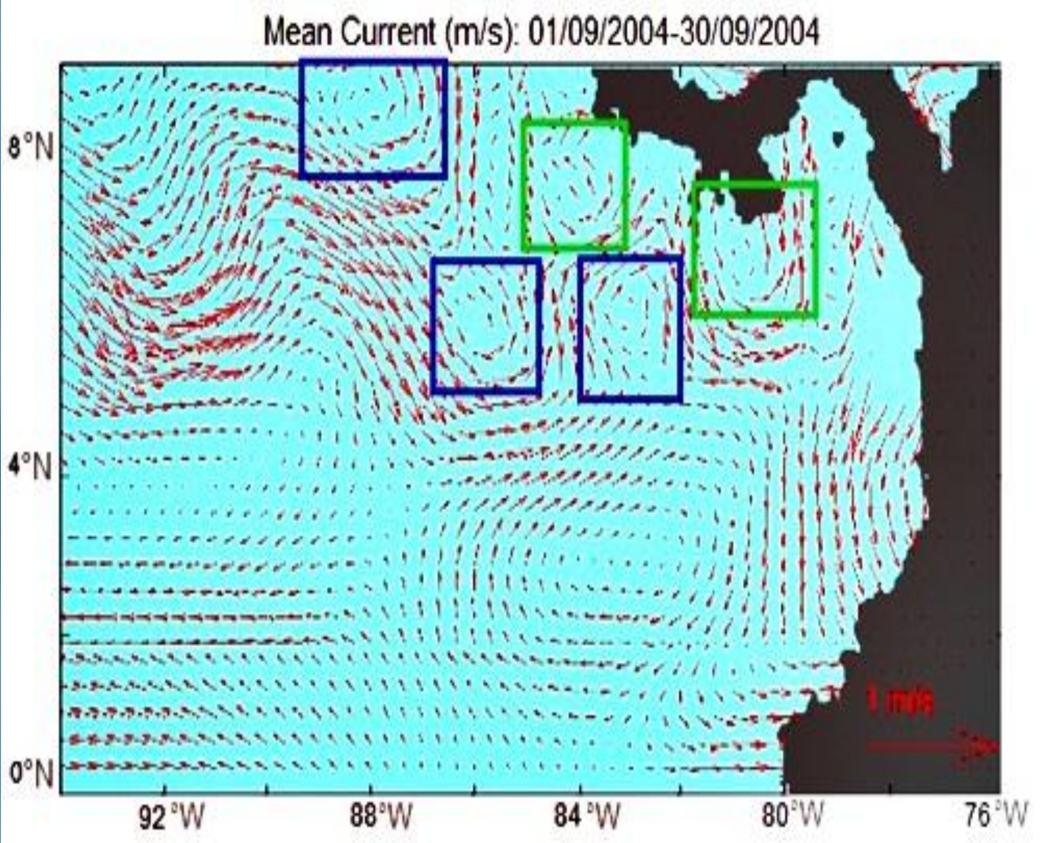

Figure 4. Eddies in the Panama Bight. The study area presented two cyclonic eddies in front of the coasts of Panama and Costa Rica during the three events compared (green inset, Fig. 4) and three additional eddies (two cyclonic and one anticyclonic during moderate El Niño years, all between 5-9ºN, 79-87ºW and associated to the NECC (black box).

CONCLUSIONS

The results suggest that the decreased velocity of the NECC and the potential barriers created by the cyclonic eddies and the anticyclonic eddy near the South American coast could diminish the passive dispersal of larvae and the potential functional connectivity between the Western, Central and Eastern Tropical Pacific. Therefore, there are implications at the evolutionary, biogeographic, and ecologic levels (dispersion rates and population rescue effect).

In contrast, during La Niña the SEC could favor teleplanktonic larval transport to the Central Pacific, material which is exported from the South American coast by CoaC, aided by the anticyclonic eddy.

In conclusion, anomalous climatic events alter the velocity of oceanic currents in the Panama Bight; consequently these could change the functional potential connectivity from September to November.

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Image source: http://www.youtube.com/watch?v=xusdWPuWAoU