Pelagic fish assemblages at the Espíritu Santo seamount in the Gulf of California during El Niño 1997-1998 and non-El Niño conditions

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RESUMEN

Para estudiar las asociaciones de adultos y larvas de peces en El Bajo Espíritu Santo (EBES), se tomaron muestras de plancton y censos visuales desde diciembre de 1995 a diciembre de 1998. Se realizaron experimentos de marcado de atún aleta amarilla de abril a septiembre de 1998. Los registros de marcado se llevaron hasta febrero del 2000. Al mismo tiempo, se realizaron cinco cruceros oceanográficos. Los censos visuales de adultos mostraron que las condiciones de El Niño favorecen la migración de especies de afinidad tropical. El índice de diversidad alcanzó valores mayores hasta de 4.5 en relación con años no Niño de 3.4 en 1996. Se observó un incremento en el número de especies de 85 en 1998 en comparación con 53 en 1996. Las comunidades de larvas mostraron un decremento en el índice de diversidad durante El Niño. Sin embargo, más del 50% de ellas pertenecen a especies mesopelágicas de afinidad tropical. Las curvas de rarefacción muestran valores mayores en el número de especies esperadas en años no Niño. Por el contrario en años Niño estas curvas muestran valores reducidos. Del análisis de agrupación se obtuvieron dos grupos que corresponden a las condiciones del evento de El Niño y a las de años no Niño. Los resultados del marcado de atún aleta amarilla mostraron dos tipos de comportamiento, uno de residencia con permanencia diaria y otro de estancias prolongadas con ausencias de aproximadamente 15 días. Durante El Niño la capa de mezcla alcanzó profundidades de hasta 70 m y la temperatura superficial fue superior en 2 °C en comparación con años no Niño.

PALABRAS CLAVE: Montaña submarina, atunes, peces pelágicos, marcado ultrasónico, diversidad.

ABSTRACT

Plankton samples and visual census from December 1995 to December 1998 were obtained to study adult and larvae assemblages of fish at El Bajo Espíritu Santo (EBES) seamount. Tagging experiments of yellow fin tuna were carried out from April to September 1998. Records of tagged fish at EBES were registered until February 2000. Five oceanographic cruises were also carried out. Visual census of adult fish suggest that El Niño conditions favor migration of tropical species to EBES. Diversity index showed higher values of 4.5 compared to non-El Niño years of 3.5 in 1996. An increased number of species, 85, in 1998 was observed in comparison to 53 of 1996. Larval fish assemblages indicate a decreased diversity index values during El Niño conditions. However, more than 50% of larval fishes during El Niño conditions belong to mesopelagic species of tropical affinity. Rarefaction curves of larval fish showed higher than expected number of species during non-El Niño years. Conversely, rarefaction curves of El Niño years showed lower than expected number of species. Two groups of samples were obtained from cluster analysis, corresponding to non-El Niño and El Niño conditions. Results of tagged yellow fin tuna showed residence on a daily basis, and homing with absence of 15 days. During El Niño the mixed layer deepened to 70 m in the area of EBES. Sea surface temperature was about 2 °C higher in comparison to non-El Niño conditions.

KEY WORDS: Seamount, tuna fish, pelagic fishes, ultrasonic tagging, diversity.

INTRODUCTION

In the southern portion of the Gulf of California, there is a group of seamounts along the coastal zone of the Baja California peninsula: Las Ánimas, El Bajo Espíritu Santo (EBES), Bajo La Reinita close to Cerralvo Island, Bajo Gorda and San Jaime are the best recognized in the region (Figure 1). Seamounts are known to have a high biological productivity. These sites attract large pelagic fishes and sharks, e.g., silky shark (*Carcharhinus falciformis*), hammerhead shark (*Sphyrna lewini*), billfish: striped marlin (*Tetrapturus audax*), blue marlin (*Makaira nigricans*), sailfish (*Istiophorus platypterus*), and black marlin (*Makaira indica*), tunas, e.g., yellowfin tuna (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), black skipjack (*Euthynnus lineatus*) and common dolphinfish (*Coryphaena hippurus*).

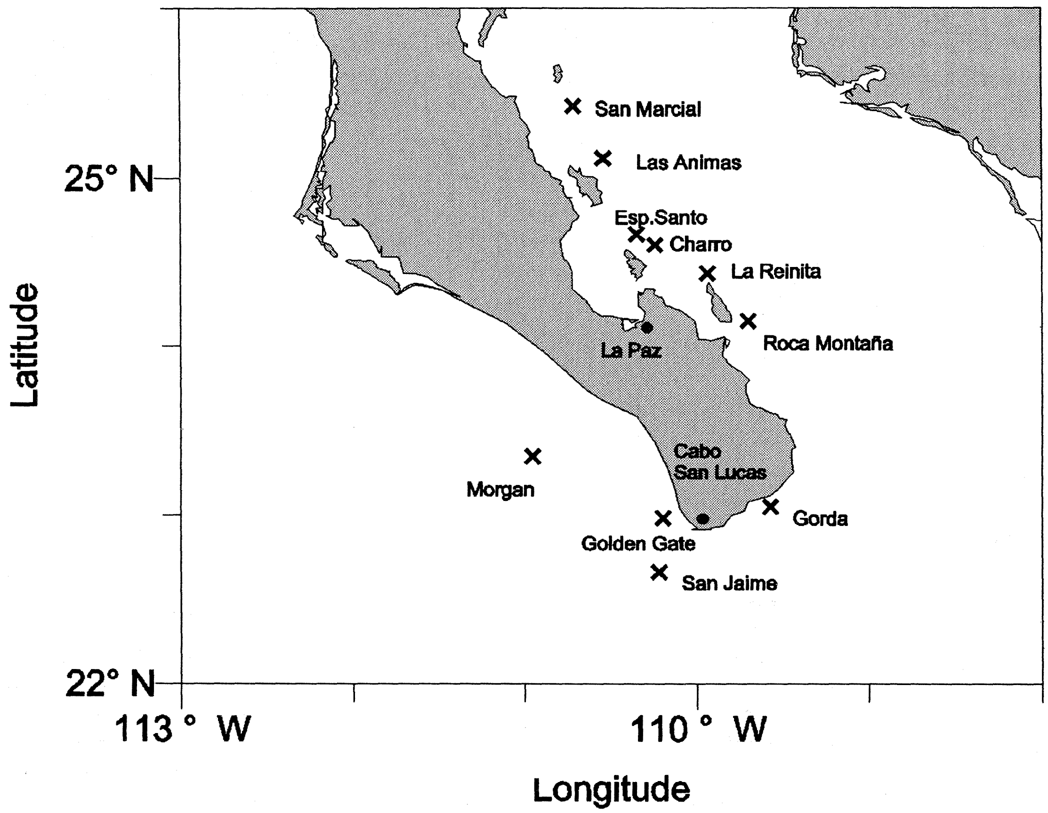


Fig. 1. Seamounts off the west coast of the tip of Baja California peninsula and inside the Gulf of California.

Presence of this diversity of fish makes these sites very attractive to the sport fishery industry.

The Bajo Espíritu Santo (EBES) seamount is located at 24°42' N and 110°18' W; its elevation from the ocean floor exceeds 890 m. Klimley and Nelson (1984) described two summits at the north and south extremes. Some of the physical effects caused by the presence of seamounts are changes on circulation patterns, changes on the thermohaline structure and a thickeming of the mixed layer (Roden, 1987).

From 1995 to 1996 monthly visual census were made to improve knowledge of the structure of the pelagic community at the EBES seamount (Muhlia-Melo, 1999). 91 different species were identified. This includes small pelagic fish, e.g., sardines and anchovies, medium size fish, e.g., pampano, jack mackarel, sierra and big pelagic fish, e.g., striped marlin, blue and black marlin, yellow fin tunas and dolphin fish among others.

Structure of the flow around the seamount during 1997-1998 El Niño is reported by Amador-Buenrostro *et al.* (2003, this issue). The hydrographic survey shows the unusual presence of a thick layer of Equatorial Surface Water. In the Farallón basin, off the EBES seamount, the existence of a 120 km in diameter near-surface cyclonic eddy is revealed by current measurements, geostrophic calculations and satellite imagery. Flow measurements also show an intense (> 0.5 m s-1) and narrow (25 km) coastal jet flowing north towards the interior of the gulf along the Baja California coast. A Lagrangian analysis of the flow field above the seamount shows the coastal jet and the convergence of the impinging flows where the influence of the bathymetry is important. Trasviña *et al.* (2000), describe the complex physical interactions at different time and length scales that contribute to enhance biomass and diversity on the seamount.

Given the importance of the EBES seamount to the ecology of the pelagic communities, we describe biological effects of the pelagic fish assemblages during El Niño 1997-1998. To do this we use visual census, plankton sampling and monitoring tagged adult fish with electronic devices. In order to compare these results, we used previous data from 1995-1996 as well as data from June 1999.

MATERIAL AND METHODS

Visual census

Monthly visual census of adult pelagic fish was carried out by free and SCUBA diving at the EBES seamount from a fiberglass skiff by divers. Divers are released upstream of the seamount and make records of abundance of fish species as they drift above it. Three trips of a 100 m transect in length by 6 m wide, allowing a time period of 25 to 30 minutes to count and record fishes were conducted. A second diver carries a plastic tablet on which the names of the common fish species are printed, he make counts and identifications of species. Temperature, depth, salinity and dissolved oxygen were measured at the location. Some observations of the type of substrate and fauna associated were also recorded.

For identification of fish and for habitat information we consulted Allen and Robertson (1994), Fisher *et al.* (1995), Jordan and Evermann (1896-1900), Miller and Lea (1972) and Thomson *et al.* (1979). Diversity indices were applied to visual census data. This method is described in Krebs (1985).

Plankton sampling

Plankton samples were collected onboard the R/V BIPII from surface tows in a six-station grid centered over the seamount, (Figure 2). In June 1998, plankton samples were collected from R/V Francisco de Ulloa on surface tows along two perpendicular lines over the seamount (Figure 2).

In June 1999 a plankton-sampling cruise was carried out on board of the R/V F. de Ulloa. Plankton samples were collected in four smaller-scale grids. One grid was located over the seamount (EBES grid), one to the north of the seamount (North grid), one to the east (Gulf grid), and one to the south (South grid), the three later outside of the influence of the seamount (Figure 3). Each grid included 6 stations, except for the Gulf grid, which only has 5. Distance between stations was 900 m. An overview of this experiment is presented in Trasviña *et al.* (2000).

Net tows were carried out on the surface (upper 1-m) at a speed of 3.5 knots (6.4 km h-1) during 5 minutes, using a 300-cm long cylindrical-conical plankton net with a 60-cm diameter at the mouth and a 505 micron mesh size (González-Armas *et al.*, 1999). A flow meter was fixed to measure the filtered volume. All plankton tows were made during daylight to avoid the bias that could be caused by night vertical migration of the zooplankton. Plankton

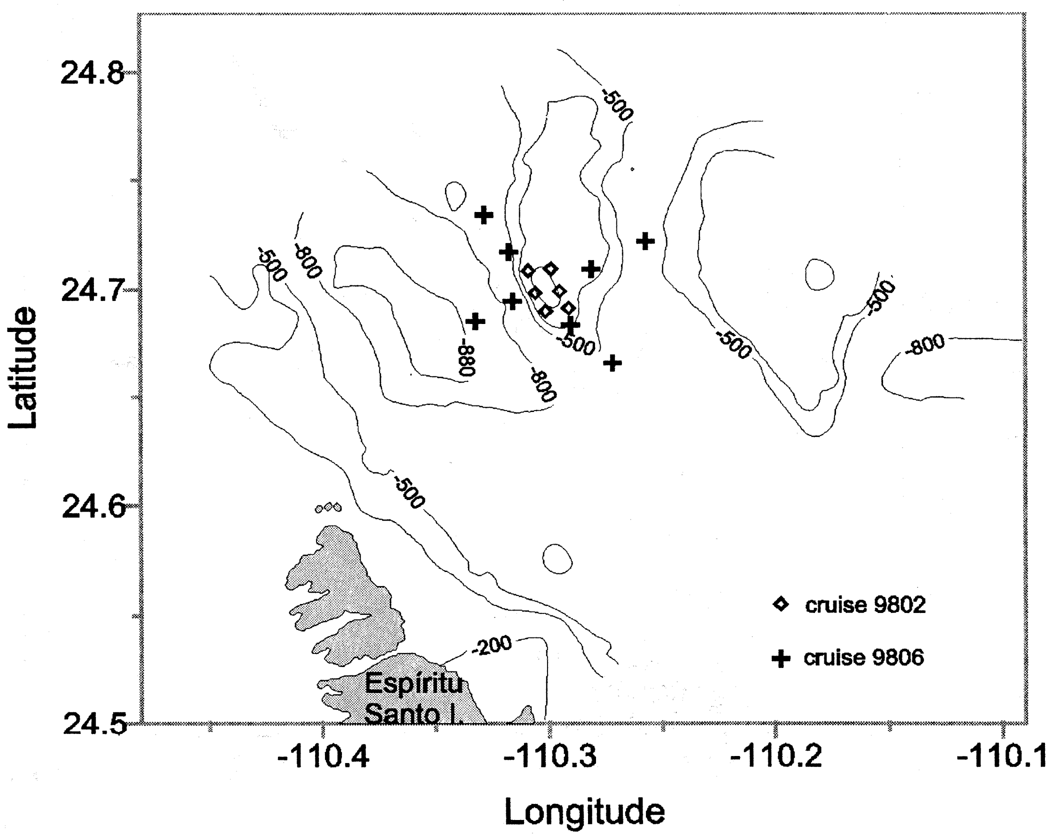


Fig. 2. Plankton sampling stations used in cruises in February and June 1998 over the EBES seamount. Cruise 9802 denoted by a black diamond, cruise 9806 denoted by a black cross. Depth is in meters.

samples were fixed in 4% formaldehyde buffered seawater. Fish larvae were sorted using a dissecting microscope. The taxonomic identification was mostly taken to the species level. When cases of early stages were found, genus or family of the specimens were given. For identification of fish larvae and for habitat information we consulted Moser (1996).

The most commonly occurring species (which made up > 0.1% of abundance) were selected on the basis of a preliminary examination of abundance data. These species made up 90% of total abundance.

To investigate diversity, we used number of species for richness (s) and calculated Shannon's Index (H') (Krebs, 1985), as:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i, \quad (1)$$

where H' is the information content of the sample (bits/individual) or index of species diversity, s is the number of species, and Pi is the proportion of the total sample belonging to the i th species.

The Rarefaction method was applied to compare diversity of larvae in monthly samples in February and June 1996, February and June 1998, and June 1999. This is a statistical method for estimating the number of species expected in a random sample of individuals taken from a collection (Simberloff, 1979).

Bray-Curtis cluster analysis (simple average link) applied to larvae species and months was used to define similarity of species present during the El Niño and non-El Niño event. This analysis was based on the abundance matrix, from the same samples explained above; outliers were eliminated to reduce bias of abundant species, the data were transformed to log $_{10,}$ (x+1)(Grioche *et al.,* 1999).

Tagging experiment

In February 1998 onboard the R/V BIP II, four mooring listening stations consisting of 1m^3 concrete block with 6 m of chain attached to 3/4" polypropylene line with flota-

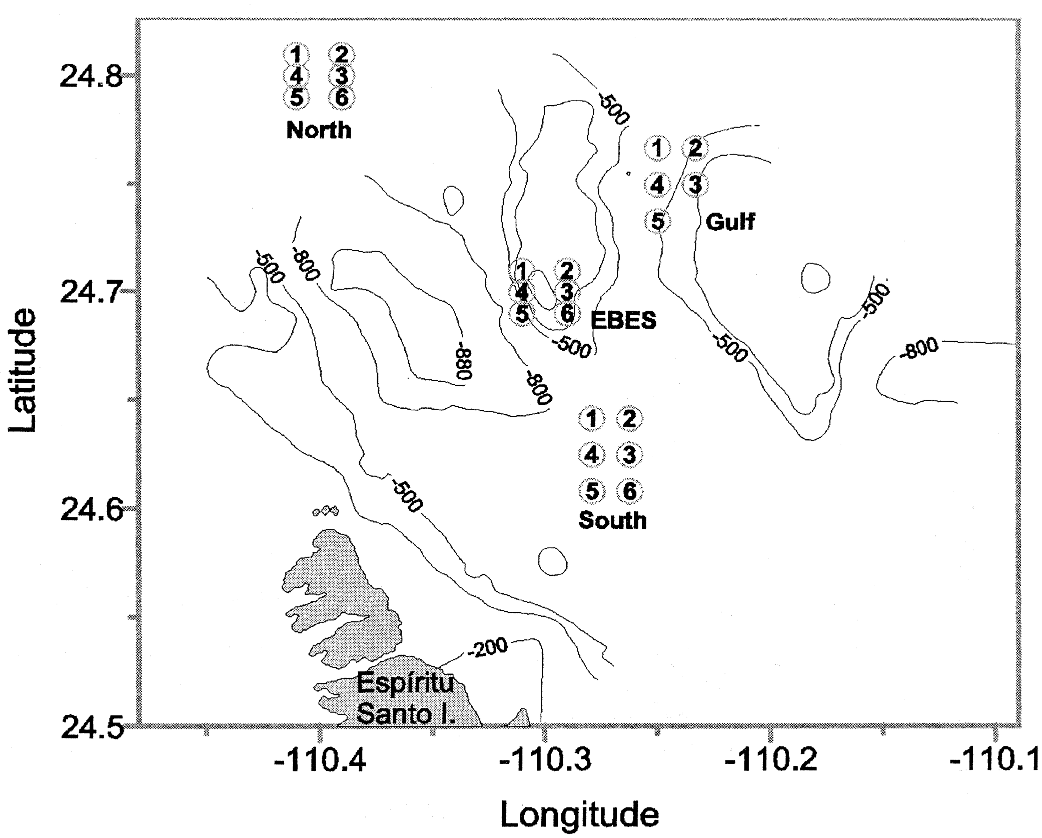


Fig. 3. Plankton sampling stations used in cruise in June 1999 over the EBES seamount, fine-grid named EBES, GULF, NORTH and GULF. Depth is in meters.

tion were installed over the seamounts Las Ánimas, EBES, La Reinita and Gorda (Figure 1). However, due to the strong currents caused two of the listening stations to move to deeper waters. Three out of four were recovered and two were reinstalled at the north and south extremes of the EBES seamount. These two listening stations were maintained with automated monitors and recorded the motions to and from the sites by fish tagged with coded beacons.

Attached below the three buoys on each mooring is an ultrasonic monitor (VR-01, Vemco Lmt., Halifax) and temperature logger (StowAway TibbiT, Onset Computers, Onset). The VR01 monitor includes a hydrophone, receiver, micro controller-based ID decoder, electronic non-volatile memory for data storage, and power supply. The receiver records the data on time when each fish carrying a coded beacon passes within a radius of 150-200 m of the mooring.

A five-day hydrographic and tagging cruise over the EBES seamount was carried out in August 1998 on board the R/V G. Sproul. Each individual was weighed and measured in total length. Salt water was pumped through a vinyl hose into the fish's mouth, across its gills, and out through its brachial aperture to enable the fish to breathe while out of the water. Ultrasonic beacons were inserted at the peritoneal cavity according to Klimley's description (Klimley *et al.,* 1998). The coded beacons are cylindrical, 16 mm in diameter and 106 mm long, and are slightly negatively buoyant. Recovery from this surgical procedure was evidenced by the frequency of return visits by tuna tagged at the EBES seamount.

Twenty-three yellow fin tuna (*Thunnus albacares)* and one silky shark (*Charcharhinus falciformis*) were tagged between April and September 1998, during the terminal phases of the 1997-1998 El Niño event. The presence of these tagged individuals was recorded through February 2000 along with half hourly measurements of water temperatures at 15 m depth (Figure 7).

RESULTS AND DISCUSSION

Results of diversity index (H') for adult fish from December 1995 to December 1998, showed higher values during El Niño event 1997-1998 than those of non-El Niño years (Figure 4). Species of more tropical affinity were more abundant during El Niño conditions, e.g. yellow fin tuna (Thunnus albacares), snappers (*Lutjanus argentiventris, L. viridis, L. aratus*), cardinal (*Paranthias colonus*) and sandbass (*Mycteroperca rosacea*).

A larger number of adult species arrive to the area of the seamount during El Niño. 85 species were found in comparison to 57 species in 1996. The main differences

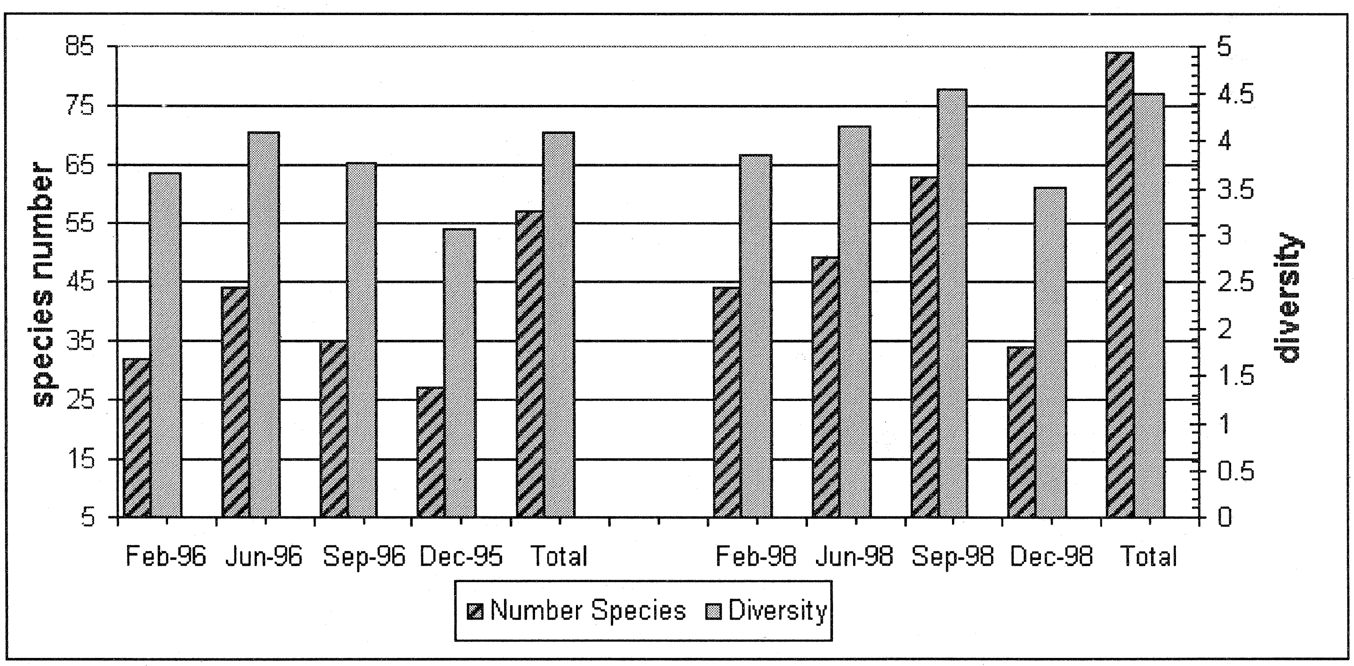


Fig. 4. Diversity Index H' for adults fishes (bits/individuals), from December 1995 to December 1998. Higher values were observed during El Niño event.

were observed during the summer season 1998, when H' index reached values of 4.5 compared to 3.75 in September 1996.

Comparison of rarefaction curves of sampled larvae showed differences between El Niño and non-El Niño years in terms of the expected species (Figure 5). Higher values of expected number of species were found in February 1996, June 1996 and June 1999, non El Niño years. Lower values were obtained in samples of February and June 1998, El Niño year. These curves were generated using the Simberloff modification off Sander's method (Simberloff, 1979).

Results of Bray-Curtis cluster analysis (simple average link) applied to fish larvae samples taken in 1996,1998 and 1999 showed basically 2 groups of species (Figure 6). The first group relates species collected in June 1996 and June 1999, non-El Niño years. Most of the species in this group belong in general to more cosmopolitan species. The second group includes samples collected during El Niño event in February and June 1998. More than 50 % of the abundant species in this group are characterized as species of more tropical affinity e.g. *Opisthonema libertate, Eucinostomus argenteus, Caranx caballus, Bentosema panamense* and *Vinciguerria lucetia.*

Results of tagging experiments indicated that the highest percentage of returns of tagged individuals occurred during September 1998, coinciding with peak (daily mean) summer temperatures. High temperatures in September of 1998 were 2 °C higher in average than those found in 1999 (Trasviña *et al.,* 2001). Fishermen captured two tunas, and one tag was found in late September. The consistent presence of three tunas was recorded for over nine months beginning September 1998, two of which have continued to frequent the seamount for over 18 months. These tuna's pattern of attendance was punctuated with brief periods of 2 to 5 days to longer periods of 15 days of absence (Figure 7).

CONCLUSIONS

El Niño conditions favor migration of tropical adult species to the EBES seamount. Diversity index of adult fishes was higher than during non-El Niño conditions. Temperate species were found in limited numbers at EBES during this warm event. They probably migrate to waters of lower temperatures.

Fish larvae diversity decreased during the advance of the warm waters of El Niño event. However, more than 50% of larval fishes identified from February to June 1998 belong to mesopelagic species with tropical affinity.

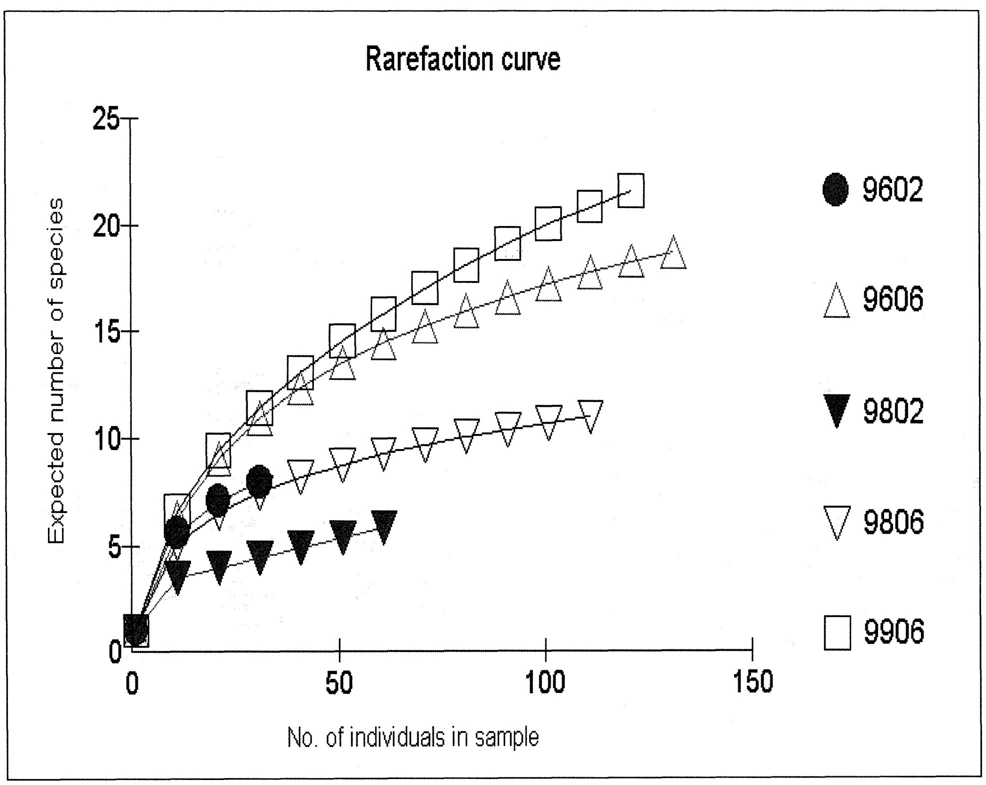
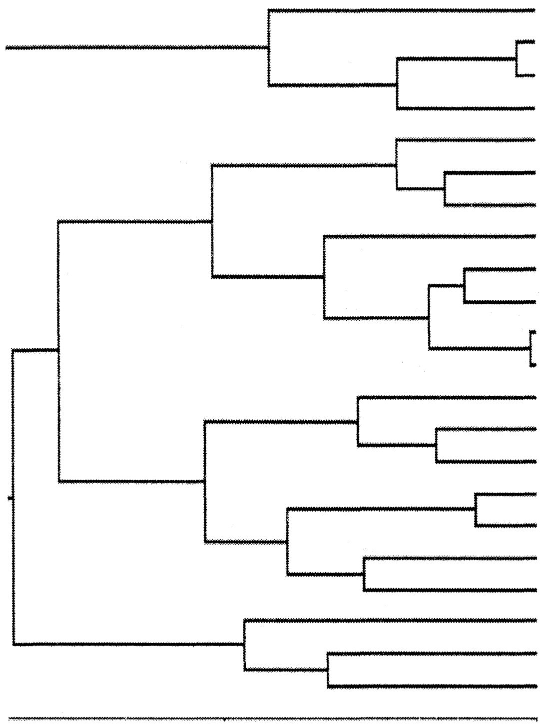


Fig. 5. Rarefaction curves for fish larvae collected at the EBES during non El Niño and El Niño years. June 1996 and June 1999 curves are non El Niño years and reach a higher expected number of species in comparison to curves from El Niño years February and June 1998.



Seriola lalandi	4				3
Sardinops sagax	7				
Scomber japonicus	8				
Engraulis mordax	7	2			
Mulloidichthys dentatus			2		2
Auxis spp			3		1
Scorpaena guttata			7		1
Cubiceps pauciradiatus		1	4		
Polydactilus aproximans		4	1		
Hyporhamphus rosae		2	15		
Mugil cephalus		8	26		
Abudefduf troschelii		8	28		
Gobiidae		9		1	7
Opisthonema libertate		2			31
Eucinostomus argenteus		15			32
Hypsoblennius brevipinnis		4			
Spheroides lobatus		6			
Harengula trissina		19	1	1	
Hemiramphus saltator		48			
Caranx caballus				27	
Bentosema panamense				16	13
Vinciguerria lucetia	1	4	14	19	18

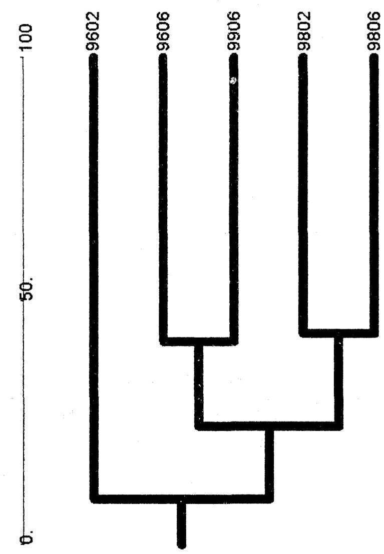


Fig. 6. Bray-Curtis cluster analysis applied to fish larvae samples based on the abundance matrix, with data from February and June 1996, February and June 1998 and June 1999.

Patterns of abundance of tagged yellow fin tuna indicate two types of behavior. A pattern of residence in which individuals are present at the seamount on a daily basis, and a pattern of homing where individuals return to the seamount after longer periods of absence (15 days approximately). Tunas seem not to be drastically affected by El Niño conditions. However, correlation between higher temperature and greater percentage of tagged tuna returns could not be substantiated due to the small sample size and the fact that many tunas have not returned since September 1998. Nevertheless, resident tunas remained at the EBES during and after El Niño.

Due to the El Niño conditions in November 1997 the mixed layer deepened to 70 m in the area of the EBES. Surface temperature was about 2 °C higher, in average, than non El Niño years.

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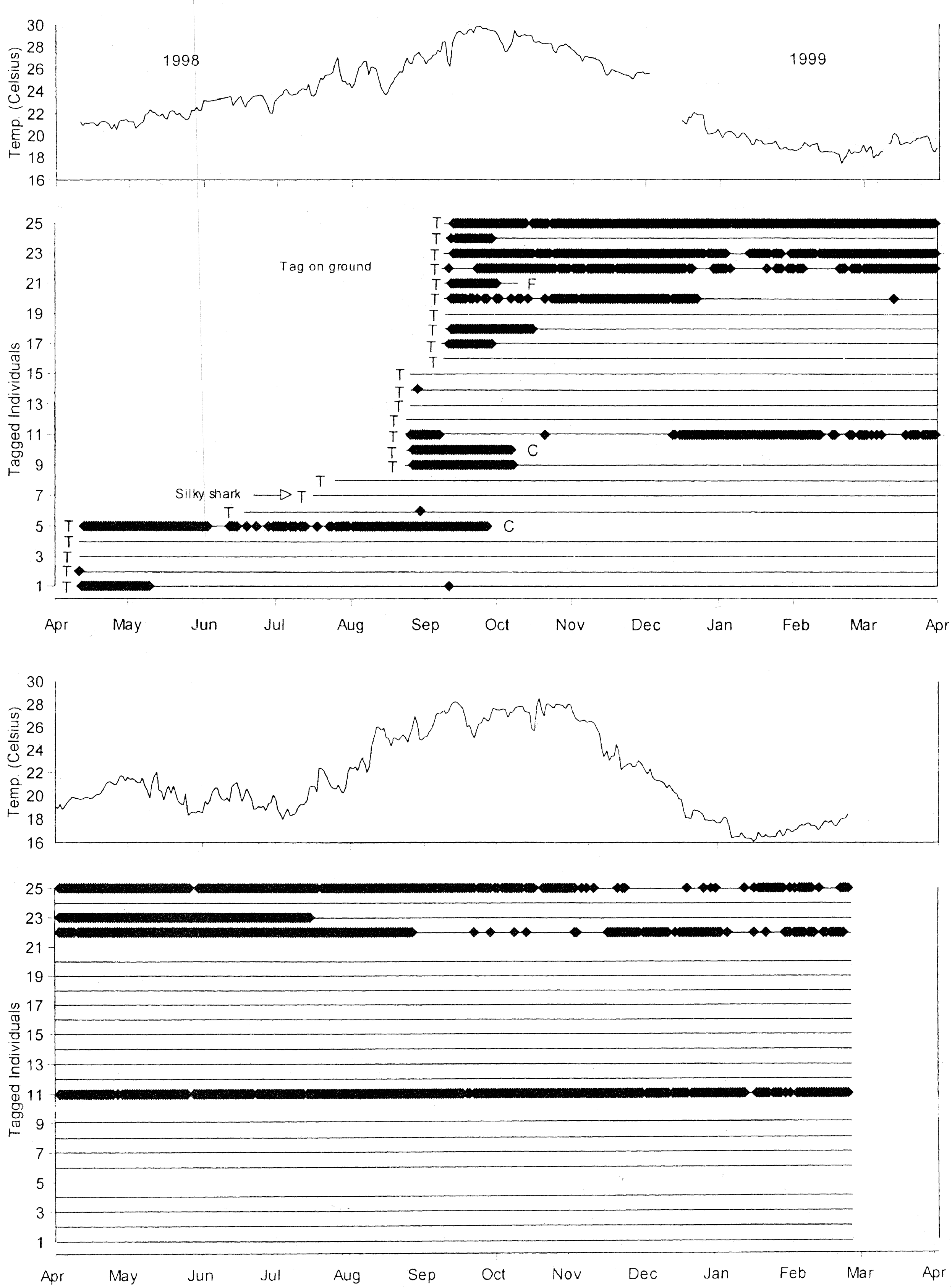

Fig. 7. Attendance of tagged fish at EBES seamount from April 1998 to March 2000 recorded for automated electronic monitors. Temperature data logger attached to the mooring at 15 m depth.

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