Preliminary Report-August 2003

NOAA-NMFS-SK Award Number NA17FD2370P

OFFSHORE CAGE CULTURE: ENVIRONMENTAL IMPACT AND PERCEPTIONS BY LOCAL FISHING COMMUNITY

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by

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Note: The following report is based on an ongoing study being partially funded by two Federal agencies, NOAA NMFS (SK Program-grant number NA17FD2370) and NOAA National Sea Grant (grant number NA16RG1611). Because funding was delayed for the SK grant, the work that is in the report is based on work that was started in June, 2002 using funds from Sea Grant.

The information will be used to develop best management practices for sustainable offshore aquaculture. To determine the environmental impact of offshore cage culture, this project will mainly focus on the localized effects of the main water and sediment quality variables on the environment. The study will also determine if the cages will act as fish attractant devices (FADs) that will increase the natural fish biomass outside of the cages. The carrying capacity of the environment to transform and assimilate nitrogen and phosphorus will help to determine the extension of pollution near the cages. The hypothesis is that there will be little net accumulation of contaminants (nitrogen and phosphorus) around the cages and little release of these wastes downstream. The wastes produced by the caged fish will be consumed by fouling organisms attached to the surface of the net, by wild fauna around the cages, and by benthic organisms. This preliminary results are no conclusive because the study is still running, however, we may show some tendencies of the main variables monitored at the cage site.

b. Describe tasks accomplished this period.

Snapperfarm, Inc. has continued its culture of mutton snapper (Lutjanus analis) and cobia (Rachycentron canadum). Eutrophication of the water column and the sediment has been evaluated since June, 2003, by monitoring physical, chemical, and environmental variables, especially relevant biotic and abiotic variables that are indicators of eutrophication. Such indicators include changes in levels of nitrogenous compounds and chlorophyll-*a* concentrations leading to primary biomass production or decreases in diversity, video taping of the area prior to, during, and after the operation.

Inorganic nitrogen in the water (ammonia-N, nitrite-N, and nitrate-N concentrations):

Two water samples were taken bimonthly at the cage-bottom-level depth (29 m depth), at the cage-mid-level depth (16 m depth), and at the cage-top-level depth (8 m depth) from each of the 16 samples sites by using an Alpha Water Sampler from the boat. Water samples were taken at north (N), south (S), west (W) and east (E) of each cage, at 20 and 40 m, and at the center of the cage. Samples were also taken at three depths in a control site (Co) (about 400 m from the cages), to determine if the changes in values are due to the effect of the cages or seasonality. Between each sampling the Alpha Water Sampler were washed to avoid cross contamination of the samples. Each sample will be immediately poured into labeled dark plastic bottle for ammonia-N, nitrate-N, and nitrite-N determination in the laboratory. Depth was estimated from the division of the wire out and the cosine of the angle. Each water sample was preserved with 2-5 drops of H_2SO_4 and was also preserved with ice into a cooler (igloo) to reduce or eliminate the bacterial activity into the bottles. The bottles were then transported to the laboratory for the respective analyses.

For ammonia-N and nitrite-N determination, each water sample was unfreeze and poured into four 15-ml assay tubing (two for ammonia-N and two for nitrite-N analysis). Ammonia-N was determined by colorimetric analysis following the Indophenol Method (Standard Method, 1998). The nitrite-N concentrations were also determined by colorimetric analysis, following the Nitroprusiade Method) (Standard Method, 1998). For nitrate-N analysis, a portion of the unfreeze water samples will be poured into two 50 ml assay tubing and subsequently the samples was passed through a packed cadmium column to reduce the nitrate-N to nitrite-N. Then the reduced samples were analyzed by the Nitroprusiade Method.

Water analyses indicated that both cages have shown similar ammonia-N concentrations, although the snapper cage received significant less amount of feed than the cobia cage during

the period of evaluation. Nitrite concentrations were low for all the months analyzed (usually less than 0.006 mg/L). Both cages had similar nitrite-N concentrations, but the control site showed lowest concentrations (Fig. 1). Nitrite-N concentrations were higher in August (when there was no nutrient input since the cages were stocked on that date). Samples in August were pooled for each depth because there was no nutrient input. The nitrite-N concentration during October, February, April and June were negligible (Fig. 2). No differences have been found among depths for nitrite-N concentrations (Fig. 3). There was also no difference among sampling sites for both cages and the control site (Figs. 4 and 5).

Nitrate concentrations have been low for all months analyzed (Usually less than 0.006 mg/L). Both cages had similar nitrate-N concentration, but the control site showed lowest concentrations (Fig. 1). December showed the highest nitrate-N concentrations (Fig. 2), compared with other months. No differences in the nitrate-N concentrations have been found among depths (Fig. 3), nor for sampling sites (Figs. 4 and 5).

Phosphate in the water

Phosphate concentrations were also low for all months analyzed (usually less than 0.003 mg/L). The control site had similar concentrations as the cages, suggesting that changes are seasonal (Fig. 1). No differences have been found among months (Fig. 2). There has been no difference among depths (Fig. 3), nor sampling site (Figs. 4 and 5).

Organic matter in the sediments

Two sediments samples were taken in each sample site (0, 20, and 40 meter of each side of the cage mooring), including the control site, by using PVC core sampler. The samples was stored into a plastic bottle and preserved with ice into a cooler (igloo) to reduce or eliminate the bacterial activity into the bottles. The bottles were then stored into a freezer until doing the respective analysis. At the laboratory, the sediment samples were unfreeze and two sub-samples of each sample were placed into crucibles previously cleaned and dried to determine the dry weight and organic matter of the sample by using the Gravimetric Method (Standard Methods, 1998).

The cobia cage and the control site showed similar percentage of organic matter in the sediments (approximately 4.4%) while the snapper cage had an average of 4.7 % (Fig. 6). October and December 2002 had the highest percentage de organic matter (5.32 and 4.79% respectively, (Fig. 7), however February and April had level similar to June and August, (when there were no feed input). No difference in sampling sites is showed for the organic matter in the sediments (Fig. 8).

Organic nitrogen in the sediments

Two sediments samples were taken in each sample site (0, 20, and 40 meter of each side of the cage mooring), including the control site, by using PVC core sampler. The samples was stored into a plastic bottle and preserved with ice into a cooler (igloo) to reduce or eliminate the bacterial activity into the bottles. The bottles were then stored into a freezer until doing the respective analysis. At the laboratory, the sediment samples were unfreeze and two sub-samples of each sample were placed into crucibles previously cleaned and dried to determine the organic nitrogen by using the Gas Chromatography Method (Standard Methods, 1998).

The control site had similar organic nitrogen concentrations as the cages, suggesting that changes are seasonal (Fig. 9). From October, the organic nitrogen concentration has increased slightly (Fig. 10). There has been no difference among sampling site (Fig. 11)

Dissolved oxygen, water temperature, chlorophyll-a concentration, water turbidy and salinity:

Dissolved oxygen concentrations, water temperature, chlorophyll-a concentrations, water turbidity, and salinity have been monitored continuously around the cages by taking data each 15 minutes with a data logging monitoring system (Data Sonde 4a from Hydrolab), and their respective sensors. The Hydrolab is installed at the rim of the Cobia cage and it is recovered monthly to download the information into a portable computer. Once the data is collected, the sensors are recalibrated, and the Hydrolab is reprogrammed, and then reinstalled to continue the data logging process at the cages.

Dissolved oxygen concentrations have remained above 5.5 mg/L the most of the time of the months analyzed (Fig. 12). The average dissolved oxygen saturation in water has been 89%.

The water temperature declined slightly from December to February approximately 1ºC, and then increased the temperature, approximating 28.0 ºC until May (Fig. 13). Although there has been some variation in the water temperature, the changes are between 1-2 ºC throughout the months analyzed. It is noted that the coldest months for Puerto Rican waters usually are December, January, and February (the coldest month). The average water temperature has been 27.3 ºC.

The chlorophyll-concentrations around the cages from December to May has oscillated a lot throughout the months analyzed, with average concentrations of 7.37 µg/L. January and February had higher concentrations than March, April and May (Fig. 14).

The water turbidity have remained most of the time below 15 NTU during December to May with peaks in mid-January and mid-May (Fig. 15). These peaks could be associated with the net cleaning process. Average water turbidity has been of 26.9 NTU

Salinity has remained homogenous throughout the experimental period with an average of 34.7 ppt (Fig. 16). There was a decreasing peak in salinity at mid-January.

Macroinvertebrates benthic fauna associated with the cages

Two sediments samples were taken in each sample site (0 and 40 meter of each side of the cage mooring), including the control site, by using PVC core sampler every two months. Samples were filtered into a sieve and identified. Results until now show that there was a decrease in the number of macroinvertebrates families during December; however, the species diversity and species evenness on the benthic macroinvertebrates did no change from October 2002 to April 2003 at the offshore cages culture (Fig. 17). There was no difference among sampling sites (North, South, West, and East, and control site) for the abundance of macroinvertebrates (Fig. 18.), Shannon diversity index (Fig. 19) and species evenness (Fig. 20) in both cages. The macroinvertebrates predominant family was the Polychaeta, followed by the Mollusk and Crustaceous.

Fish fauna around the cages

Censuses were taken at two submerged cages in Culebra Island, Puerto Rico. Each cage was sample by recording species and relative abundance of fish at different depths (top, ring and bottom of the cage). This study gives a qualitative description of the composition, distribution and relative abundance of fish associated with offshore-submerged cage systems for the culture of snapper and cobia in Puerto Rican waters. Videos taken before the cages were installed indicated few fish in the water column. Videos taken from June 2002 to August 2003 suggest that there are significant increases in fish numbers found near the cages. Approximately 9700 fish were censused in one year. Fish belong to five orders, 20 families and 37 species. 99% of individuals belong to nine species. Carangidae has been the most abundant family, with 8 species and 79% of total fish censused. The most abundant Carangidae specie were (*Caranx rubber, Caranx crysos* and *Decapterus* sp), but also Haemulidae, Acanthuridae and Labridae were present in significant abundances (Fig.21). Some species were present in large schools and others were also present in small quantities or solitary. Genus Caranx and Decapterus usually

were concentrated in schools. The genus *Caranx* had been previously considered to have species with a tendency to associate near floating objects (Hunter et al. 1967). Jacks are considered strong swimming predators of open sea with a clear tendency of forming large schools (Humann 1994). Eighteen species have commercial importance (58% of total fish) and may have ecological importance since they act as nursery structures for some species, having a possible effect on the redistribution of juveniles.

Most of the species encircling the cages moved in schools, some in large and others in less dense schools, depending on the specie. *Decapterus sp.* presented the larger and more compact schools, possibly because of the smaller sized individuals. Deudero et al. (1999) affirm that the size of a shoal is quite variable depending on the ecology of the species and on its propensity to be preyed upon. They reported carangid species making use of the schooling tendency, as either a defense against predators or as a mechanism for an enhanced predator foraging activity.

From the organisms identified, 17 species are reef type, 10 species live typically in both reef ad oceanic waters, and 9 species were typically from oceanic waters. However, fish abundance were higher for oceanic and reef-oceanic type species (41 and 40% respectively). Many reef fish use a variety of habitats during ontogeny, often showing distinct spatial separation in settlement areas, nursery areas, juvenile and adult feeding areas (Appeldoorn et al. 1997). All the observed specimens of the genus *Acanthurus* were juveniles and mainly distributed on the top of the cage. The fact that there is a considerable aggregation of recruits in an area means that either reproduction or survival is patchy (Hall and Lennert. 1992). In this sense, it is important to note the importance of these cages as a nursery structure where juveniles could find the conditions required for existence and survival. The same results have been reported by other studies of floating objects (Deudero et al. 1999). These cages may have important ecological consequences since they act like nursery structures for some species, possibly having an effect on the redistribution of juveniles.

Thirty two species were present with juvenile organisms, meaning that the cages would be acting as nursery structures and may increase the potential fisheries in the area. Some of these species were: *Aulostomus maculatus, Mycteroperca venenosa, Lutjanus mahogony, Holacanthus ciliaris, Acanthurus coeruleus* and *Acanthurus chirurgus*. The genera *Acanthurus* was present only in juvenile stages and its distribution was usually limited to the top of the cages. Also, *Thalassoma bifasciatum* was limited to the top of the cage. No other specie showed difference in depth distribution.

The location of the cages may have an effect on wild fish distributions. All the species identified are present on coral reefs, but some are more common in open waters, such as jacks, *Sphyraena barracuda* or *Scomberomurus cavalla*. The submerged and floating objects represent a substrate for many organisms (Hunter et al. 1967) and there begins the aggregation effect of the cages. One explanation for the attraction to drifting materials is schooling companions; the other is the fact that they provide a substitute substrate for species undergoing a change to another mode of existence (Hunter et al. 1967). It is also believed that submerged objects give rise to an increase in media complexity (Deudero et al. 1999), which increases this attracting effect. Since these fish, are opportunistic feeders (Humann 1994), their presence around the cages could be attributable to food acquisition. The presence of species exclusively associated to coral reefs, *Holacanthus ciliaris,* can be explained since Culebra is an island surrounded by coral reefs. And although the cages are located far enough from these coral areas, specie can freely navigate across discontinuities within their home range with the help of strong zonal currents (Appeldoorn et al. 1997).

The species that exhibited a solitary behavior were the bigger ones, such as *Sphyraena barracuda, Echeneis naucrates* and *Scomberomus cavalla,* among others. These species seem to take advantage of their large body size and represent the higher trophic level around the cages.

The lack of studies carried out on similar habitats does not allow close comparisons. However, comparing with other fish aggregating device (FAD) studies, the richness value obtained here is rather high taking into account that 37 species belonging to 20 families were found. This could represent a good potential to enhance the fisheries of the area. Since the results reported here correspond only to the fish community associated with the submerged cages among the months analyzed, it is suggested that the aggregation effect of the cages is significantly strong to the wild fish community.

Weather information

The weather information has been taken from a meteorological weather station located at Ceiba, Puerto Rico (the Roosevelt Roads Meteorological Station). The average tide, air temperature, heat index, dew point, wind speed, and relative humidity data were downloading daily into a desktop computer by Internet. The average monthly tide at Culebra passage has been usually less than 0.8 knots, with an average of maximum ebb and flood tide of -0.78 and 0.71 knots, respectively (Fig. 22).

The air temperature, heat index, and dew points have followed the same pattern, as expected (Fig. 23). The air temperature has remained similar as the water temperature, with an average of 27ºC from June 2002 to April 2003. The coldest and warmest months were January (mean of 25.2ºC) and August (mean of 29.7ºC), respectively.

The average wind velocity from June 2002 until April 2003 have been 9.93 mph, with September, October, and November having the softest wind while June and February the strongest winds (Fig. 24).

There has been high relative humidity in the air during the months analyzed (Fig. 25). Usually the humidity is above 70%, with an average of 76%. The average pressure from June to March was 29.9 in Hg. However, the wind has oscillated from month to month. September has the highest pressure while October, November, and December the lowest (Fig. 26).

Current Meter Deployment

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Overview

This report documents the second in a series of current meter monitoring events to be conducted in the vicinity of the Snapperfarm, Inc. open ocean cage mariculture site in waters off western Culebra Island, corresponding to the period from April 10, 2003 to June 20, 2003 and is described as event 1. Ocean Spar Technologies, Inc, designers of the mariculture cages, conducted the first deployment as event 1 (see the Culebra 1 Deployment Report from May 30, 2002 to June 6, 2002) as part of the cage placement and mooring protocol. This is the first deployment by the Open Ocean Cage Mariculture (OOCM) Group of the University of Puerto Rico (UPR) at the Culebra environmental monitoring control site indicated in Fig. 27. This report intends to describe the S4 velocity and temperature data and to provide some basic context for its interpretation.

Oceanographic Instrumentation

An InterOcean S4 vector averaging current meter was used in this deployment. The technical specifications and operational characteristics of the S4 current meter were presented in the Culebra 1 document and are not included herein; additional information is available from

http://www.interoceansystems.com/s4main.htm. The S4 velocity data were corrected for magnetic variance by 13.28°.

UPR's S4 is very similar to the instrument used by Ocean Spar at the cage site. One notable difference is that UPR's S4 is equipped with a thermistor and yields a temperature time series for the deployment period whereas Ocean Spars' instrument is equipped with a pressure sensor and therefore yields pressure (~depth) data. Our S4 was previously used in a study on the transport through the Mona Passage, at La Parguera and in a number of student research projects. Prior to the cage mariculture study the S4 was sent to InterOcean for maintenance and calibration, at which time all four external sensors were replaced and new firmware installed.

Deployment Location

The S4 was mounted in a subsurface, taut-wire, configuration at mean depth of 14 m (47 ft); bottom depth at the site is 27 m (90 ft). The mooring is located at the environmental monitoring control site south of Cayo Luis Peña, and southwest of Bahía de Sardinas. Its GPS coordinates are 18 16.418°N, 65 19.764°W, at the S4 marker shown in Fig. 24. This location is approximately 375 m due south of the SnapperFarm cages. The hard sandy bottom at this location is flat and mostly featureless, just like the bottom at the cage site, and there are no nearby bottom structures that could generate bathymetric flow steering. As shown in Fig. 27 bottom contours are aligned along a northwest to southeast axis (~ 320°-140° true).

S4 Configuration

The S4 configuration parameters are listed in Table 1.

Results

The monitoring period from April to June 2003 marked the transition from spring to summer weather patterns in the Western Tropical Atlantic. During mid April we were under the influence of a swell-generating low-pressure system off the Atlantic coast of the United States. These are typical winter and spring conditions in our region, with the low-pressure systems moving eastward across the Atlantic while creating a fairly predictable sequence of meteorological conditions in Puerto Rico and the US Virgin Islands. Two more similar weather systems influenced local conditions in late April and mid May, bringing closure to the spring season. Starting in June local weather conditions switched to a mode where low-latitude low-pressure waves start arriving periodically from the east creating a pattern of oscillation in the strength of the Easterly Trade Winds. The weather patterns affecting the local region are quasi-periodic in time with approximate periods of one to two weeks.

The flow regime observed during this brief monitoring event is characterized by

- predominantly along-isobath flow along the axis 300-320° ↔ 120-140° true;
- strong semidiurnal (two cycles per day), and weaker diurnal (one cycle per day), tidal components with amplitudes of 20-30 cm/s;
- mean, or low-frequency, northwestward flow with a record mean towards 300° true at 8 cm/s;
- quasi-periodic 5-day to weekly component in the low-frequency signal;
- northwestward flow (towards 300°-320° true) occurs during the flooding tide (as the sea surface elevation is increasing) whereas the ebbing tide coincides with southeastward flow (120°-140° true);
- peak flow lags the tidal peak by about three hours (approximately a quarter of a semidiurnal cycle);

- the tidal ellipses are elongated along bottom contours to the point of nearly a straight line so that changes in direction occur very quickly, there is very little transport towards land and the velocity vectors are observed to swing back and forth across the offshore hemisphere.

The full velocity data are presented in the form of current direction and speed time series in Figs. 28 and 29, respectively, and as *u* (cross-isobath) and *v* (along-isobath) component time series in Figs. 30 and 31. Due to the large number of velocity data points these figures are kind of messy to look at; however, several important features are most easily seen in this way. The closely spaced oscillations correspond to the dominant semidiurnal oscillations of the velocity vectors.

In Fig. 28 we can observe a line created by the clustering of data points near 300° degrees that corresponds to the mean, predominant, flow direction; a corresponding, less defined, clustering is observed around 120°. Note that northwestward mean flow prevails throughout the entire record. Fig. 29 shows the flow speed (velocity magnitude) throughout the record. The record maximum value of 47 cm/s (91.3% of a knot) occurred on April 16 at 16:25. Typical daily high speeds seen in Fig. 29, and also reflected in the 90th percentile, are in the order of 30 cm/s (~60% of a knot). The mean magnitude of the flow is represented by the scalar mean speed, 15.2 cm/s, and by the 50th percentile speed, 13.0 cm/s (Table 2).

Lunar perigee (Moon closest to Earth) and zyzygy (full or new moon) coincided during April 15 and lunar declination was not far from 18°. Tidal currents often reach bi-annual maximal during, or a few days after, these astronomical events known as King Tides. Note that the maximum record speed was observed on April 16 and keep this relationship in mind in the subsequent discussion. For the representation of the 2-D velocity vector data a natural, bottom-aligned, coordinate system was chosen. In these coordinates, *v* represents the along-isobath axis with positive/negative *v* pointing towards 300°/120° true whereas *u* is the cross-isobath axis, with positive/negative *u* towards 30°/210° true. Figs. 30 and 31 clearly show the along-isobath component to be the predominant transport direction. The record-mean *v* (8.4 cm/s) is two orders of magnitude higher than the corresponding mean *u* (-0.02cm/s). Note that the largest amplitude of the tidal *v* component occurs near April 18 with daily values of ~40 cm/s.

A complementary view of the velocity data is presented in the form of progressive vectors, or pseudo trajectories, in Fig. 32. The directional distribution of transport per unit area is presented in Fig. 30. Steady mean northwestward flow is indicated in both figures.

The NOAA software predicted tide at Ensenada Honda, the NOAA tide station closest to the Snapperfarm cage site, for the full record period is shown in Fig. 34. This figure is intended to serve as reference in the description of expanded data intervals to follow. Two time periods a) April 11-17 (Figs. 35-37) and b) May 22-27 (Figs. 38-40) have been selected for a more detailed view of tidal flow behavior and its variability.

First, in the Culebra 1 Deployment Report I made the following statement that in view of the current data set is clearly wrong. “The tide at Ensenada Honda precedes the tide at the S4 mooring by about three hours. It turns out that due to similar time lags the NOAA tides at Ensenada Honda are a good predictor for the velocities at the cage site (Fig. 30); peak high tide at Ensenada Honda is in phase with northwestward flow at the cage site whereas peak low tide at Ensenada Honda is in phase with southeastward flow.” This statement was based on information provided by Ocean Spar regarding the times at which their velocity data were taken; I applied a 3-hour delay to the data to account for California time.

As shown in Figs. 35 and 38 the peak flow is not in phase with the Ensenada Honda tide. Northwestward flow (towards 300°-320° true) occurs during the flooding tide (as the sea surface elevation is increasing) whereas the ebbing tide coincides with southeastward flow (120°-140° true). Peak flow lags the tidal peak by about three hours (approximately a quarter of a semidiurnal cycle). This leads me to believe that the surface tide at Ensenada Honda is in phase with the surface tide at the cage site. Future monitoring should clarify this inconsistency between the two data sets.

The dominant semidiurnal and diurnal tidal components in the velocity time series were filtered out (or smoothed out) of the raw time series so the lower frequency components could be observed (Fig. 41). The most prominent features in this figure are the mean *u* and *v* components and the quasi-periodic 5-day to weekly component in the low-frequency signal. The 5-7 day variability in the velocity time series could very well arise from the previously described meteorological forcing.

Progressive vector trajectories from corresponding time periods in 2002 and 2003 are compared in Fig. 42. Although flow speeds and bottom steering are comparable in both data sets, the mean flow directions are towards opposite ends of the axis of main variance. Significant inter-annual variability is suggested in these data.

Power spectral densities vs. frequency (1/hours) plots of the rotated velocity components are included as Figs. 43-45. The most prominent peak (highest power) corresponds to the semidiurnal tide (0.08 cycles/hour), followed by the diurnal tide (0.04 cycles/hour). Note that in the expanded low-frequency end of the spectrum the next highest peak corresponds to approximately 5.2 days. The cross-isobath component exhibits a number of additional peaks towards the high end of the spectrum, which probably arise from seiching of waters in La Sonda de Vieques passage.

Fig. 46 shows the mid-depth temperature record at the control site. The record mean temperature was 27.76°C with a minimum of 27.01°C and a maximum of 28.28°C. The typical diurnal temperature range was ~0.2°C.

The three-day period from May 23-25 was unusual in that the flow did not reverse direction and a persistent northwestward current prevailed. One possible explanation for this behavior lies in the large-scale regional mesoscale eddy field that populates the northeast Caribbean Sea. As shown in Fig. 47 the synchronicity of the mesoscale geostrophic currents north and south of La Sonda de Vieques at the time would promote persistent northward flow into the Atlantic. Anyway, this figure serves to illustrate the large-scale circulation that may influence conditions at the cage site.

Part 1: Social Component report
Culebra Political Ecology Fieldwork

by
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28 April –1 May 2003 fieldwork on Culebra

Mission: providing initial political ecology questions
for Dr. Janet Bonilla, UPR Mayaguez

Acknowledgements: Many thanks for the warm hospitality of a number of Culebra's people, including the kind assistance of people in Fish and Wildlife, UPR, Coralations, the Fisheries Association, and local church, social work, and education groups. May Snapperfarm follow their wish, being simultaneously successful in raising cobia and participating in community grassroots development on Culebra.

Our participation in this interesting project with brief allotted fieldwork aims to produce bare bone lines for future full investigation to be carried out by UPR. To verify this report's "facts" and understanding of the various interest groups' perceptions, there needs to be more in-depth life and work histories, the core field method of political ecology/cultural anthropology utilized in Culebra.

Demographic/employment

In 2000 a census indicated that Culebra's population was 1,868, of whom 1,626 were Puerto Rican. Illegal foreigners are not covered but locals estimate an additional 1,000 Dominicans. Add to this figure off-islander, mainly Americans and Europeans owning 800 houses.

Off-island migration is the norm, especially to Puerto Rico (PR), the Virgin Islands, and New York. In general, people on Culebra are encouraged even forced to go off-island for advanced medical care and education. The goal (federal/island level political directives) is to keep the population fairly low. Unemployed, ambitious or professionals tend to leave Culebra.

A twenty-something turtle watch employee for Coralations says 85% of his peers no longer live on Culebra, but on St. Thomas, the "Big Island" (local name for mainland Puerto Rico), and in the States. A number of students go on to Fajardo for University. Of his peers who did stay, most are divided between drug money, construction jobs ($9-15/hr.), some sweet medical factory positions, and then the highly desired government office jobs.

The majority of people on Culebra do work for the government (e.g. *palas*). The most gifted and trained tend to hold office type jobs, especially for the federal, island, municipal government. Culebra in one way can be seen as left with zero unemployment, since those who remain jobless turn down menial offers.

Construction companies (e.g. to build a sewage plant) often contract their labor from the Dominican Republic. Perhaps 1,000 Dominican men live here, crowded into little houses. Another source of menial labor comes from Vieques, as will be discussed.
Some few can earn money, extra money, or get free rent is to be the caretaker/housesitter for one of the 800 houses owned by off-islanders.

The three largest employers on Culebra are the Municipality, DENR, and RD Medical (a medical tubing factory). RD Medical is employing young menial laborers from Vieques because Culebrenses don't like working the assembly line for $9/ hr.

This overall situation has implications for Snapperfarm as a future employer. Who will they be able to hire given who they will need to hire in the capital-intensive high-tech side of their industry? And, who will be willing to work for them as menial labor on Culebra?

Perspectives on Menial Work

Parents of Culebra youth on island without fulltime jobs sometimes perceive their children as being full of laziness and having a lack of shame for going on the dole. The parents attribute this

to a lack of drive, discipline and the influence of drugs. Ironically, a common perception held by Americans (including Euros) is that Culebrense labor in general will quit, preferring to subsist on foodstamps, government housing and land that continue to be parceled out through the traditional *parcela* system.[1] The roots of the US dole and the federal underlying agenda to hold the islands in a relatively undeveloped, low population state need to be examined and addressed before social change is possible.

Meanwhile, in the wider context of constrained local infrastructure where youth have been highly discouraged from remaining on island, Snapperfarm's future unskilled job offers might actually encourage more day labor to come over. This is likely despite their good intentions of encouraging local youth to stay. Thus, Snapperfarm's best possible contribution to the community might be in terms of environmental education at local schools and informal education programs, as well as those in Vieques. It is important that the culture of conservation permeates the next generation no matter where they live, and those who stay closer to nature on islands will understand the critical role of human/environmental interactions.

For the new MPAs to function in the sea, this education is essential, along with the top regulatory level's ability to incorporate visual and economically sensitive management regimes designed with locals to generate local adoption and compliance. Otherwise, the MPAs inevitably stay at the level of paper tigers. Brut enforcement has never worked.

Note that the distribution of *parcelas* is highly political in terms of what lot one can get. An American qualifies for a *parcela* if they meet the resident requirements required of everyone (and to live on the land and build a house. Most land surrounding the Airport is *Parcela* land. The poorest, including the Dominicans, are settled on the hill by the airport. They get by with latrines for toilets. Thus, it is conceivable that Vieques people and other outsider workers could settle in as a marginalized labor force, and have cheap places to live, if Culebra developed in a way that provided these jobs. Perhaps the current commuting ferry service recently implemented between Vieques and Culebra specifically to bring over the medical factory workers is an attempt to block this scenario and keep others from settling in Culebra.

Politics

Three levels of government operate on Culebra: US federal, PR island, and Culebra municipal. The majority of the island is "Red" (status quo, i.e. *Partido Popular*... instead of "Blue" for statehood or outright independence). These political affiliations are taken seriously, splitting extended families so that they avoid socializing even on holidays. Snapperfarm, though not political, indirectly must support those in power and operates business under the majority position of status quo.

During April 2003's fieldwork, we participated in a one day event put on by the key three interest groups presenting themselves in alliance to U.S. Fish & Wildlife for funding. Unfortunately, the request itself has recently been turned down. However, the process of trying to function as an alliance is important for the future, given force in numbers and coordinated environmental education efforts that they can mutually support from different angles. The triangle is:

(1) **Snapperfarm**. Coordinating economically with the Fisheries Association, led by one strong local leader, Lourdes (daughter of the beloved longterm former mayor of Culebra who quietly got the Navy ousted and stated discussing environmental objectives for the island). The Fisheries Association provides the docking and shore space as well as selling the supplies to Snapperfarm.

(2) **Turtle Project**. Coralations --run by Mary Ann Lucking (8 years PR and 4 years Culebra)—is working with the local US Fish and Wildlife --headed by Theresa (18 years on island) to create this project. The project leads small groups of visitors to the beaches who must stay the whole night and carry out counting. The idea is to invoke as sense of being serious and respectful, countering the days of eating turtles and their eggs.

The project aims (a) to provide youth with environmental training and jobs as guides counting nesting sea turtles, esp. leatherbacks and hawksbills, and (b) to provide ecotourism business for local hotels and restaurants by insisting that anyone going to see the turtles all night with them first must have paid for a hotel.

A few youth are already being paid by Coralations for guiding ecotourism to the turtles. Last year the pay was $5/hr., and this year it is $8/hr., depending on the amount and directives of the acquired grants.

The Turtle Project is trying to coordinate efforts with local DENR who control beach permits and science on the turtles. But, their ideas on what constitute effective and safe studies on the nesting turtle's conflict. DENR sometimes has withheld beach permits to the Turtle Project while granting others access. One antithesis to the project granted a recent permit was the PR tourism film crew who came with bright lights at night to increase tourism outside the bounds of the Turtle Project's eco-sensibility.

(3) **Marine Reserve**. The coral biologist from UPR Rio Piedras, Dr. Edwin Hernandez Delgado is funded by DENR and is working with CORALations currently funded by US Fish & Wildlife.

DENR is in charge of the Marine Reserve. Herein lies a disputed jurisdiction. The local Culebra Board, ACDDC, run by Nester for the municipality claims that the mayor's office is in charge of the Marine Reserve which DENR says they still control at the federal and island level. In addition, the Fisheries Association has an active interest in further advancing the Marine Reserve, linking it back to the former mayor's push for conservation.

The mayor of municipality controls the *parcela* system and the distribution of desirable jobs through the ACDDC which is part of the municipality. Again, he now thinks that they also control the coast and marine areas. However, NOAA and DENR, with the new marine reserve coming online, feel this is a misconception and see that they will have to produce regulations to put the municipality back in its place. Or, the other option NOAA is considering would be to establish a separate independent trust fund outside the municipality that is managed by a group of stakeholders (e.g. include the UPR coral biologist who is doing studies for the marine reserve; Coralations; municipality reps; US Fish and Wildlife). Then, this group might be able to maintain the reserve, implement its management plan, and attend to other marine resource issues as the pot of money grows, such as turtles. Nester, the director of ACDDC, agrees in principle with this independent trust fund group that incorporates the various interest groups.

The issue of control will be a key for the success of the management plan. By creating a new group, NOAA could hope to gain local participation and compliance, and avoid the tragic possibility of any monies getting lost to the general government treasury (Eileen Alicea, NOAA/NOS International Program Office, D.C.).

Community in the context of development

Please see the fine historical study by Claro C. Feliciano's *Apuntes y comentarios de la colonicacion y liberacion de la Isla de Culebra* (2001).

Here is a simple outline of Culebra society's interactions within their community hierarchy and with the outside influences. The US Navy came in 1903, when cows, sold to the mainland, were a main industry. In 1985 the last of the cattle died out due to lack of water, lack of workers, dropping beef prices, and perhaps an apocryphal cow stepping on unexploded Navy ordinances. The farms grew over in cactus and sat as rather unused assets until real estate booms.

Relations among the people and the Navy were good; Culebra women would quite often found husbands from the American Navy. Crime was low, despite a fair amount of rum smuggling, and in the 50s and 60s there were still only foot police.

In 1975-76 the Navy left. Reports are mixed on whether the Navy left quietly or if there was a bit of donnybrook. One official version is of a peaceful even befuddled naval departure over the "mouse that roared", Culebra with its Harvard-trained lawyer.

When the Navy pulled out there came major social structure change. The 1975 population was 575, and after the Navy left most people moved to NY, St. Croix, and St. Thomas, and the Big Island. Culebra became a more a place of older people, with very few workers. In general, Culebra did not keep up pace with the development speed of the Big Island.

About ten years ago, Hurricane Hugo hit. Houses of cinderblock withstood the winds, yet few wooden houses survived. Fruit trees were expensive; FEMA came but did not help to replant fruit trees after the storm. Only recently some have been replanted. But at this time there were very few ferries or tourists, and scant hotels. There was only one public car/taxi.

In 1996 a new big ferry for cars began operation, greatly increasing access and tourism. Today's Culebra hosts huge weekend bashes on the beach, especially on holidays. There is more movement than ever among youth, bringing in MTV dreams and expectations. The adults do not appreciate the deluge of day trippers, yet feel helpless. The enterprises at the beachfront benefit; the costs of sanitation and police protection land on the Culebra.

A lot of US people in particular had been investing in land. Around the turn of the millennium, real estate has been developing rapidly.
This was a different class of developers than the first rich homebuilders. The current developers have come to build on smaller bits of rezoned land, gambling on apartments and condos, desiring to pump up land speculations. An example is the condominium complex of Costa Bonito, nicknamed *Costa Feita*—Ugly Coast by angry locals. People felt helpless to stop it. It sports 145 apartments on 15 acres, built despite 8 law violations and much community protest. Note that Mary Ann Lucking of Coralations has correctly linked this sort of development with a reduced quality of life and opportunities for Culebra people. She has been extremely active, even facing death threats, in countering such development abuses, using her educational capital to protest in high courts, citing erosion and ecosystem degradation, and educating locals to these dangers and rounding up their support.

It will be important to know how land enters the market and what could motivate people to hold on to what they still have. This relates to the goals of Snapperfarm, Coralations, the Turtle Project, and even the Marine Reserve. There are currently 5 main finca owners: Marque, Nieve, Claro Feliciano, Antonio Lugo, Diversio Gonzalez. There are also smaller farms. Some owners are developing parts of their farmland to rent apartments and to sell. This brings in short-term profit money to those with farms.

The island still has no lawyers, no judges, and no court system. People arrested for bad crimes are taken to Fajardo. Most planned births are still in Fajardo, like the rest of the medical system.

The ferry system is now very busy bringing tourists. Again, most goods and services require a trip to the mainland, but sometimes the ferry is too full to even bring Culebrenses, especially on those weekends, causing frustration among locals. Puerto Rico today forbids private boats from taking passengers between Culebra and Fajardo, the mainland port. Drug dogs only recently began coming over on the public ferry on weekends. However, there is no kind of enforcement in terms of private boats that come, so folks bring in drugs in the ferry before the big weekends, and after, and on boats other than the ferry. Local police, since local, don't arrest relatives for drugs, or illegal fishing. Some locals benefit from drug money as in the US.

The Marine Reserve faces the deluge of private boaters at sea, especially on weekends and holidays that are uncontrolled in terms of numbers, their fishing, and anchoring. Some unknowingly casually drop the anchor onto those commonplace unexploded ordinances left behind by the Navy. Only the main tourist beach land has been carefully swept clean of years of bombing practice refuse.

Danger from unexploded ordinances is a largely un-discussed/undisclosed type of pollution on Culebra, certainly ignored by tourism interests. Teresa heading US Fish and Wildlife stays very active in this regard. She, herself, has risked tip toeing as through a mine field to avoid being blow up to study the nesting of the 60,000 sooty terns that vortex into Culebra once a year to reproduce. Vieques and Culebra were subjected to napalm. There are stockpiles of nasty military chemical substances on these islands that are not clearly exposed or cleaned up due to great expense and laissez faire.

Sewage water (i.e. black water) years ago emanated from just a few private houses flowing it into the sea, but now, with increasing density increase from tourism and businesses, the sewage quantity is awful, and on the horizon is only more construction and tourism that will continue to impact water quality, thus life in the sea.

Fishing for food rather than income

Culebra has become over fished, and most people have shifted into construction in terms of earning income. Fishing for food is another matter and continues unabated. Thus, this Project must focus on the wider community's fishing and tourist sport fishing instead of the handful of proclaimed fulltime fishers. Fisher in Culebra is more someone with a few fish.

Currently in Culebra, it is hard to define any particular group as fishers because there is always some male who is fishing and sharing fish with his family and/or extended family. The preferred fish include *capitan*, *mero*, and red snapper. Preferred denotes a first class; there is also a second class of less preferred fishes.
Culebrenses eat fish approximately three to four times a week. Some is caught, some is bought. A number of people dive three times a day, lobstering and spearfishing. Fish are sold in the street and to restaurants or supermarkets.

For purposes of selling the preferred, highest price fish, there are fish houses in Fajardo and Vieques. Culebra's Fishing Association used to have a fish house that is now considered outdated. The Fish Association has not invested in maintaining one of its original functions as a processing plant. Now it is mostly a scuba/gas station/hardware store. Paying the lowest prices, they tend to buy up some of the lesser quality, older fish. Hence, those with fish say selling to the Fish Association is a last resource.

The Fish Association believes in the Marine Reserve, having seen the days of large catches disappear. The Fish Association has been proposing a marine reserve since 1981, for the very

reason that there are not a lot of fish left, so why not turn the area into a reserve and get the government to protect it. They want federal money to guard the marine reserve and to make it illegal for fishers to enter the marine reserve.

Hence, the Fishing Association has needed to refocus their business interests away from fishing. They support cage aquaculture in alliance with Snapperfarm, providing the space to Snapperfarm who down the road may sell the Fish Association its fine-fleshed cage cobia product.

Note that the Fish Association is perceived by the community as largely an extended family and friends. In a conundrum, Snapperfarm is working closely in conjunction with the Fish Association. Snapperfarm to give back to community need to widen its activities in terms of community outreach and education.

Snapperfarm, Inc.

To date, community perceptions of Snapperfarm are totally positive, with people looking forward to training, jobs, and available fish to supplement what they catch.

Snapperfarm's plan for an on-island hatchery and for an industrial scale aquaculture farm is embraced at the ideal level. It will require a number of labor positions that most likely will not be of interest to Culebrenses, unless the salary and status is perceived as high.

Some youth say they would not risk their life for Snapperfarm diving to depth three times a day. Either nitrox diving technology or multiple shifts of divers would make diving jobs safer given that the cage bottoms currently sit at 90'. Merit and pay might also attract trained youth. And, Carlos teaches dive courses for youth in the summer, and will be teaching 10 kids in summer 2003.

Snapperfarm initially promised that 80% of its labor force would become Culebrense, a figure that now gives them pause. Since living and working on Culebra, this seems unlikely. But, they are refocusing their energy into education which can contribute to the community, shifting local ideals and practices. Both Snapperfarm and the Turtle Project aim to train local youth in conservation and marine management in Spanish**.** Besides the schools, there are at least two informal groups involved in education on island to be included.

One is the Educational Association of Culebra, a NGO working directly with about 26 welfare families, and the other are the two nuns who are working with pre-adolescent kids after school. The nuns would be open to environmental studies/aquaculture hands-on experiences for their children during their two-week summer period. Tati would like to be included in the loop via Teresa at US Fish and Wildlife who recognizes her community influence. The poorest families perhaps could be coached and incorporated in some way.

SCALE FOR FUTURE SNAPPERFARM GROWTH

Snapperfarm has leased rights to an area of water. Some people wonder about the maximum density in term of future cage development to conserve water and product quality in that leased area. Three cages was the estimated development for the current water space and water depth. Careful studies of the area need to asses water quality to maintain the local ecosystem. Ecological studies based on the finding of the present leased area need to be carefully analyzed before entering into new leasing agreements.

Marketing and harvesting opens new opportunities for local involvement in areas of packing, transport, and shipping to local and foreign markets.

Suggested topics to investigate for Dr. Janet Bonilla, University of Puerto Rico

We hope Dr. Bonilla will be funded to carry out a questionnaire and fieldwork for the local community at large, beyond the few men identifying themselves as fishers and those who are outright members of the fish association. Fishing, as on many islands worldwide, is often only one of multiple occupations. On Culebra at this point in history, few people would cite full-time fishing as their occupation. This is important to understand, given that many households still rely upon extended family members fishing for subsistence sharing the fish, and perhaps also generating a bit of income or covering costs via sales to local restaurants, supermarket, or to fish houses in Fajardo. It is critical not to discount or dismiss the fishing effort from this part-time fishery —from youth to retirees— who will not outright identify themselves as fishermen. Yet, their fishing provides desired fish to the diet and is part of the informal economy of Culebra. As such, it must be considered when weighing cultural conservation with resource management of the island. This activity would interact with future MPAs in a way not yet examined.

MPA

Perceptions and knowledge of new MPA, and how it is introduced will be interesting to follow on Culebra. Again, if it is seen as biologically logical and economically beneficial by locals and for locals, it stands a chance of being honored. What role can the Fish Association play in its acceptance? Snapperfarm?

Fishing Effort

Questions in order to frame this more general and accurate understanding of fishing effort and its social importance on Culebra would include understanding the following:

- Does anyone in their family own boats
- Do they ever get fish from the person who owns the boat
- What boats are in the family and who uses them
- Who owns and is responsible for boat's maintenance
- Where are they kept
- Actually go visit the boats and see their condition/ engines/ocean-going capability, safety
- Actually meet those who know how to fish and who go out to sea to see gear for fishing/ask about local knowledge of ecosystem, see if target species, multiple species, bi-catch)
- Ask then go with who and where people fish from shore, either swimming out or wading out, or casting from shore
- Does the family have a freezer; actually look in the freezer as ethnography
- How many times a week does the family eat fish
- When they do eat fish
- What's the source of their fish
- Do they buy it or fish it themselves
- Do they buy from store or is there reciprocity/trade of goods or services/family unity and gift giving. Etc. among family members around fish

Social Framework

Place this more focused Culebra fisheries material within context of basic Culebra social organization obtained from new life and work histories, or utilizing others' research (e.g. excellent work by Manuel Valdés Pizzini and David Griffith (*Fishers at Work, Workers at Sea,* 2002) on Puerto Rican fishers within context of the broader labor economy). Carlo C. Feliciano can also glean an historical overview from the history of Culebra.

- How do they define family/ how extended and where living - what are their ideals of family obligations
- Where were parents from; where did they live
- Where did family members grow up
- How many brothers and sisters; and where do they live
- Where do they work if off Culebra/are there any remittances sent back or those who return with savings who provide capital for fishing gear or who retire and fish

Vieques and Culebra in the Balance of Labor

Material on neighboring Vieques will grow in importance as cobia aquaculture catches on and proves profitable.

How does Vieques' labor already interact with the social economy of Culebra? For example, Vieques teenage workers are being ferried over to the medical tubing factory (a transport service recently started specifically for the factory) for menial jobs that Culebra youth and others disdain. Therefore, would Culebra youth and others be interested in jobs offered by Snapperfarm in the future if the jobs were menial?

A study of Culebra youth employment and out-migration could provide information on the types of employment Snapperfarm could realistically offer that would attract locals. Residents who are not locals joke that to lure labor, they will need to offer a cool image titles, uniforms and beepers.

Interestingly, there is a feeling by non-local residents, shared by some retired locals who have returned from work elsewhere, that locals are reliant on a "welfare" mentality held over from the old Navy handout days. Some local feel that the US government still wishes to keep them dependent on the government, and the mainland for almost all goods and services, healthcare and pharmacies being a major example of local frustration.

Besides the promise of Snapperfarm, only real estate is being developed on Culebra. This development is currently a font of desirable local jobs outside government offices. Construction jobs are a major source of income for locals as well as illegal migrant islanders. The best positions go to locals in terms of working on the plum projects and attaining the more highly paid skilled posts. Mainland PR and US investors, having gotten the island rezoned for smaller lots, are rapidly building second homes and vacation spots.

Snapperfarm is still to small and young to do more than promise work down the road when there are harvests, a hatchery, and more cages in place. Their business strategy is to maximize harvests by becoming as mechanized and high tech as possible, from cage cleaning devises to automatic feeding shoots and harvesting tubes. This is not labor intensive but capital intensive, and makes profitability sense. Scale is necessary to match the high priced market demand that they will be generating. They will require skilled people who to date are not available locally. The most educated youth have needed to seek professional jobs off-island, unless they take social work and municipal type employment on Culebra.

In any case, one has to ask in the long run if Vieques youth will be the real source of aquaculture development's largely unskilled labor force in Culebra, despite Snapperfarm's good intentions and commitment to provide local jobs to the community once established.

Realistically, how would increasing Vieques youth presence in Culebra affect the island? Increased social relations are probably the obvious outcome. Vieques youth who see opportunities on a less populated island could easily settle down, intermarry, increase the Culebra population, and thus informal fishing effort and pressure on the system of shared communal lands.

Vieques, itself, could offer other environmentally appropriate cage farm sites, but the social side of establishing aquaculture business on Vieques could be more intricate than on Culebra, and thus the original site selection on Culebra.

One would need to understand how Vieques' far larger population than Culebra's is still reliant on fisheries for food and cash.

More, Vieques must be considered a potential source of marine antagonism and conflict once Snapperfarm has expanded and established cage aquaculture for cobia in waters previously utilized in common by all fishers. Snapperfarm could face hostility in waters they now lease. Their rights might be informally contested, with increased theft, threats of poaching, and desire/frustration among Vieques fishers in particular. Recall that these waters have been traditionally shared without marine tenure or concession rights, or leasing by individuals or companies.

One would want to verify the following initial leads on employment pressures and Vieques generated fishing effort:

(1) 100 fishing boats in Vieques, divided into four groups
(2) Vieques' conch and lobster factory employs 200 workers
(3) Vieques fishers fish in St Thomas, St Croix, and Culebra, and sell a lot on the Big Island
(4) These fishers already respect nothing (e.g. MPA, reserves)
(5) Vieques has terrible unemployment
(6) Vieques had a bra factory that closed one year ago and lost a critical approximate 1000 jobs
(7) With the Navy pulling out of Vieques in mid 2003, they lost another 500 jobs

Turtle Tourism

As far as Turtle tourism as another way to find youth employment, one would verify if:

(1) Vieques and Fajardo people still eat turtle meat, and eggs as aphrodisiac still dug by Culebra men
(2) Vieques/Culebra adults have less respect for turtles than kids who are learning turtle conservation-friendly practices at a young age in island schools

Coralations and US Fish and Wildlife doubt that the current scientific method of drilling into the turtle shell to tag the leatherbacks is wise. The consensus is that local DENR acts too rough with the turtles. What is the science on this? This needs to be mediated as does access to the beach via DENR permits.

The Turtle Project's goal is to combine turtle ecotourism with turtle science. It would be interesting to compare this with any less eco-focused turtle tourism happening outside of Coralations jurisdiction

References:

Claro C. Feliciano. 2001. Apuntes y comentarios de la colonicacion y liberacion de la Isla de Culebra.

David Griffith and Manuel Valdes Pizzini. 2002. Fishers at Work, Workers at Sea: A Puerto Rican Journey through Labor and Refuge. Philadelphia: Temple University Press.

Part 2: Social Component Report

By

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Objective

The aims of the social component of this proposal is to obtain a picture of the different perceptions, attitudes, and behaviors held by the residents of Culebra regarding the introduction of the new industry, open-ocean cage aquaculture. The long term goal is to explain to the fishing community and general public located in the Municipality of Culebra, Puerto Rico concerning the innovations of this new technology in terms of environmental, legal, economic, and social impact.

Achievements

Between January and March of 2003, the investigators reviewed the existing published and non-published materials regarding the social features of Culebra and reviewed literature relating to similar studies in other parts of the world. Also they submitted a Consent Form for approval to the UPR-Mayagüez Committee for the Protection of Human Subject in Research (IRB) (See Appendix A). During March, Dr. Bonilla and Jessica Rodríguez, her research assistant, visited Culebra and identified the fishing community, as well as several community leaders as key informants for the project. Twenty (20) fishermen were identified among the general community of Culebra, which according to the USA 2003 census, consists 1,700 habitants. These fishermen constitute the entire sample representing the fishing community. In addition, three key informants were interviewed on that occasion. They agreed that theirs name could be revealed for research purposes. They are Ms. Lourdes Feliciano (Representative of the Culebra Fishermen's Association), Mr. Anastasio Soto (Ex-mayor of Culebra, a fishermen since his childhood, and ex-president of the Culebra Fishermen's Association), and Mr. Aquilo Feliciano, also an ex-mayor in Culebra, fishermen and ex-president of the Culebra Fishermen's Association. The three key informants agreed with the introduction of the open-ocean cage aquaculture techniques in Culebra and have been collaborating with Snapperfarm, Inc. They represent the position of the Administration of the Culebra Fishermen's Association.

Between March and June of 2003, the interview instrument was developed to obtain information concerning perceptions, attitudes, and behaviors held by the residents of Culebra regarding the introduction of open-ocean cage aquaculture practice. There are two sections of the instrument: general community section and fishing community section (Appendix 3). The interview instrument has four parts: (1) socio-demographic information; (2) description of the fishermen's work; (3) knowledge and perception concerning the aquaculture project in Culebra and aquaculture in general; and (4) attitudes toward the implementation of this technique in Culebra, as well as in other places. On April of 2003 a meeting was conducted with Drs. Daniel Benetti and Sara Meltzoff, University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS), and Dr. Janet Bonilla (University of Puerto Rico, Mayagüez Campus). During this meeting, Dr. Bonilla described her visit to Culebra to Drs. Benetti and Meltzoff and they offered Dr. Bonilla feedback concerning the interview instrument.

During May and June of 2003, Dr. Bonilla worked on the final version of the interview instruments, with feedback from personnel of the UPRM Sea Grant College Program. Finally, travel arrangements were made to visit Culebra during the first week of August of 2003. Dr. Bonilla and two research assistants (Jessica Rodríguez and Melissa Rodríguez) will visit Culebra to conduct interviews with the members of the fishing community and of the general community.

Projections

Table 3 includes the time schedule for the months ahead (August to November).

c. Explain special problems, differences between scheduled and accomplished work, etc.

Strong currents during the sampling periods, especially during full moon, still cause unexpected problems. We had to re-design our diving plan to ensure safety for our divers.

We formerly reported that the current meter (S4, InterOcean Systems) was not functional. However, after it was repaired it was deployed, readings were taken and are included in this report.

NOAA representatives within the Federal Government are encouraging us to continue taking samples past the proposed sampling period. They suggest the collected data will document the impact of this open ocean aquaculture project. This data will be useful to public (such as environmental) groups, governmental agencies, entrepreneurs, and to the scientific community.

2. Expenditures:

a. Describe expenditures scheduled for this period.

Because expenditures were primarily made from NOAA National Sea Grant (grant number NA16RG1611) for the first report period, expenditures for travel, additional equipment, and materials have been made from this SK grant.

b. Describe actual expenditures this period.

The more expensive equipment items were: salaries (including assistantships), a COD reactor, a laptop computer (for use in the field), housing for a video camera, scuba equipment, a second Hydrolab ($11,800, including probes for chlorophyll, temperature, salinity, oxygen), and travel to the Culebra site.

c. Explain special problems, differences between scheduled and actual expenditures, etc.

After repair of the current meter, current data has been collected and reported. Even though we have collected biofouling samples, we are behind on the analyses because the graduate student assigned to that area has decided to work with another project. We have provided funding for another student having prior identification experience. We also need to install a hood in our laboratory for completing the biofouling sample analyses. We are negotiating with the university physical plant to determine the requisite paperwork to apply to install the hood. The hood will not be purchased from this project; however, some materials will be used for the installation. Oherwise, we are adhering to our sampling itinerary. Only the lack of the current meter is behind at this point.

Prepared by: _____

Signature of Principal Investigator Date

Appendix 1-Figures

Fig. 1. Dissolved nutrients at the cages and the control site

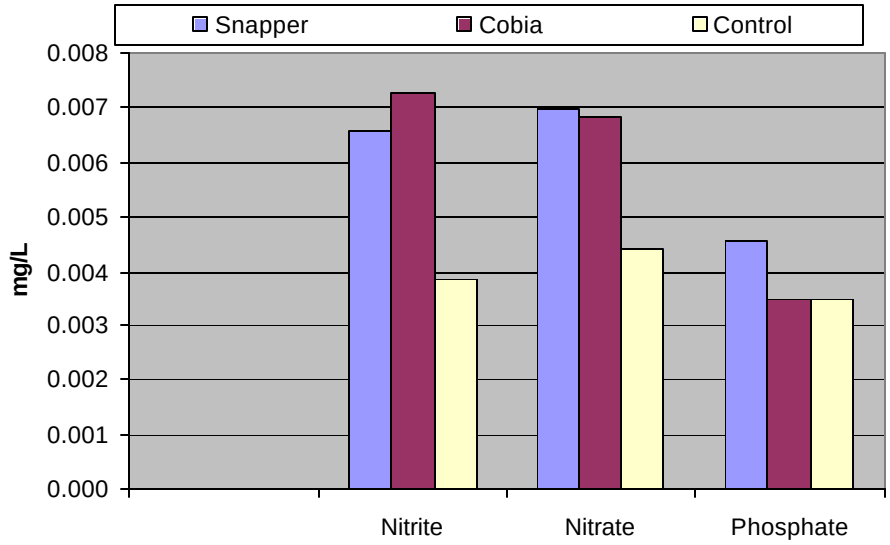


Fig 2. Temporal variation of dissolved nutrients in the water column Offshore cage culture

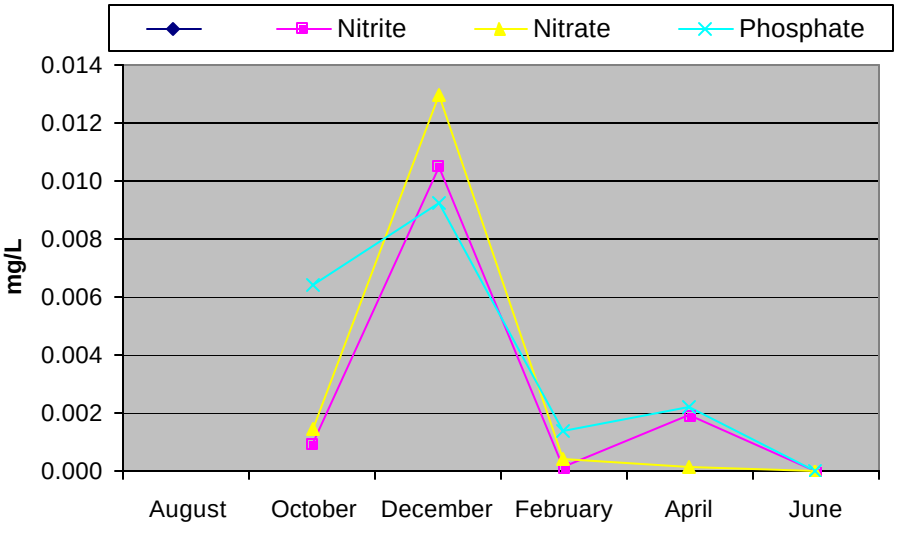


Fig. 3. Vertical variation of dissolved nutrients in the water column Offshore cage culture

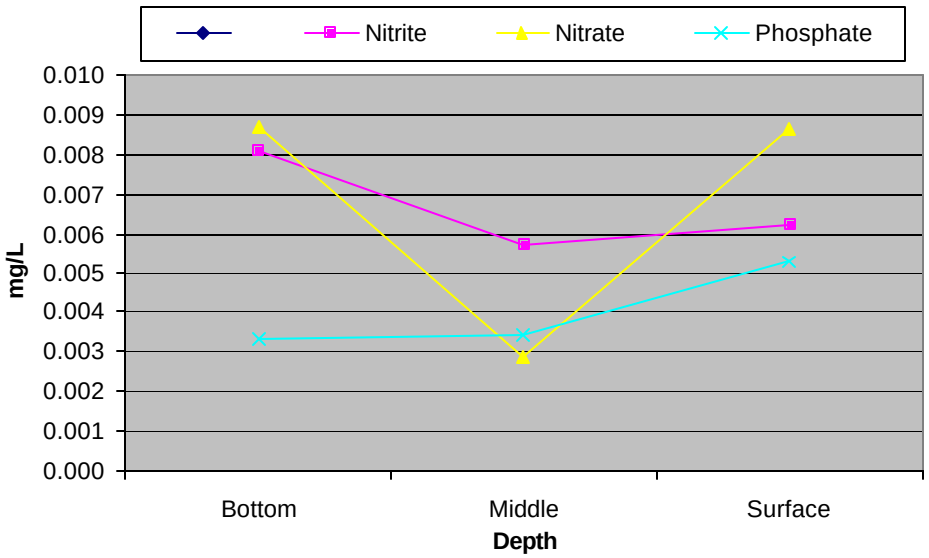


Fig. 4. Dissolved nutrients in the water column-Snapper cage

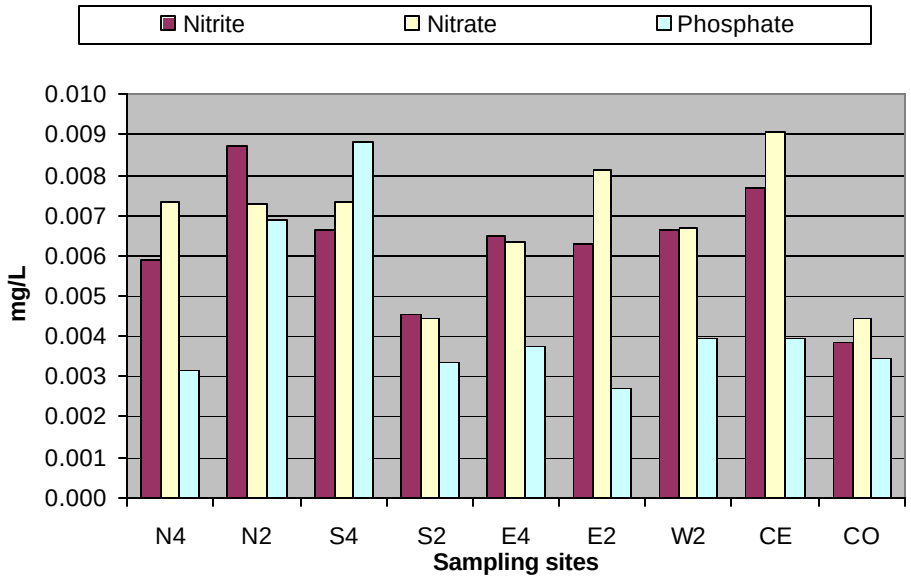


Fig. 5. Dissolved nutrients in the water column-Cobia cage

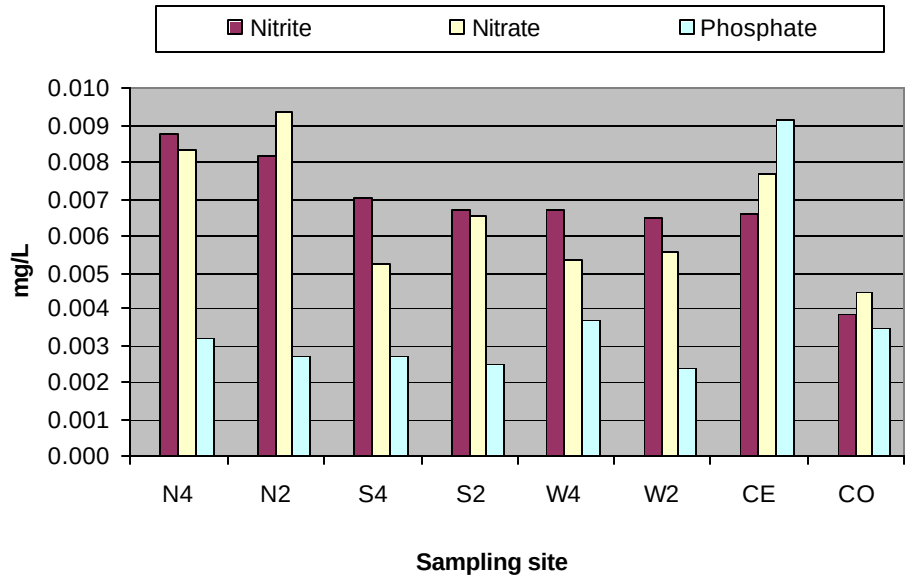


Fig. 6. Mean of organic matter at the cages and control site

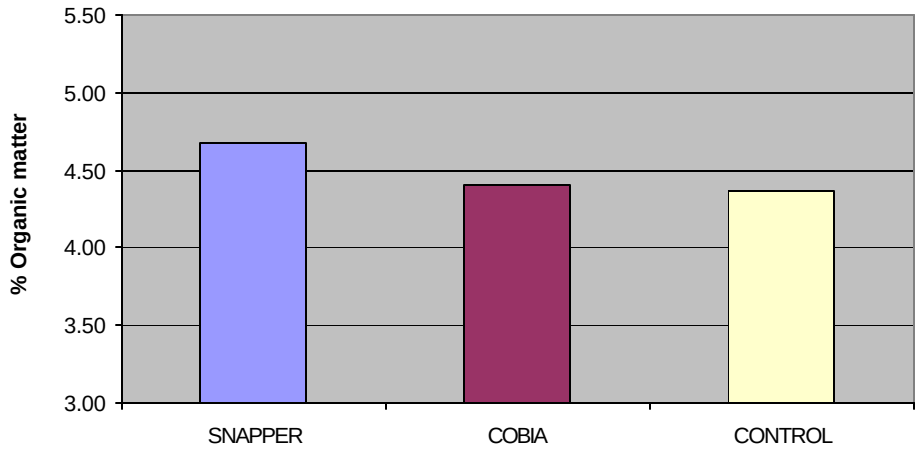


Fig. 7. Monthly variation of organic matter

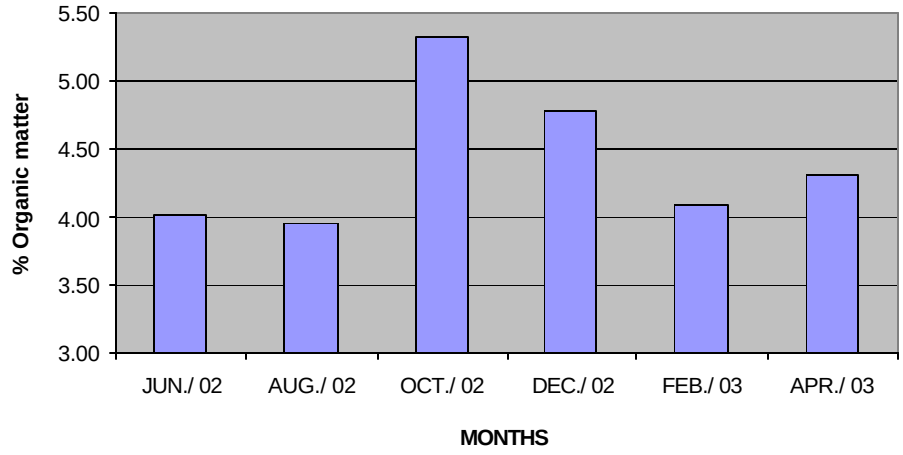


Fig. 8. Organic matter at the sampling sites

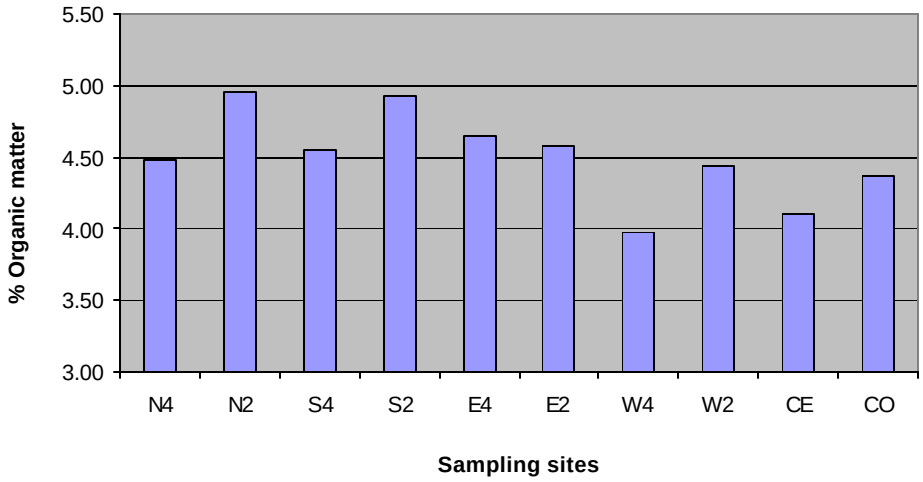
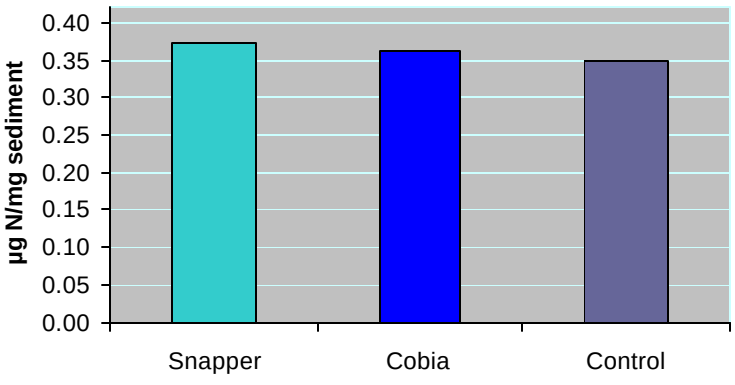


Fig. 9. Organic nitrogen in the sediments at the cages and control site



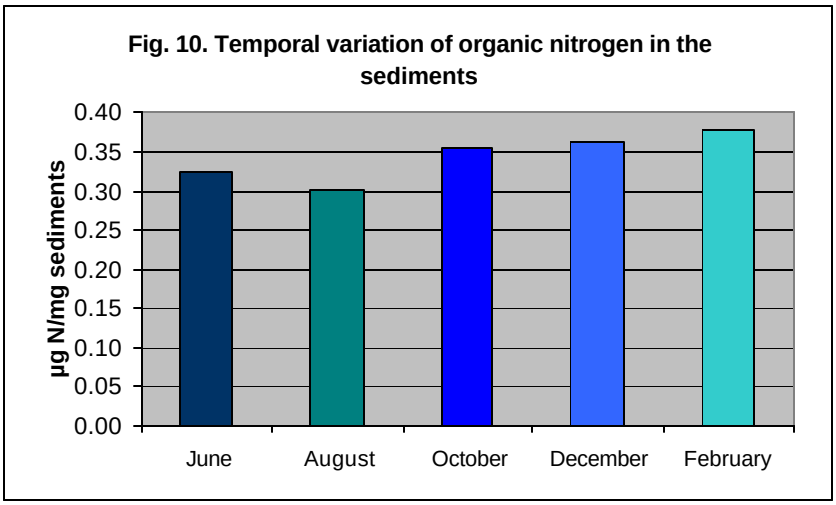


Fig. 10. Temporal variation of organic nitrogen in the sediments
µg N/mg sediments
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
June
August
October
December
February

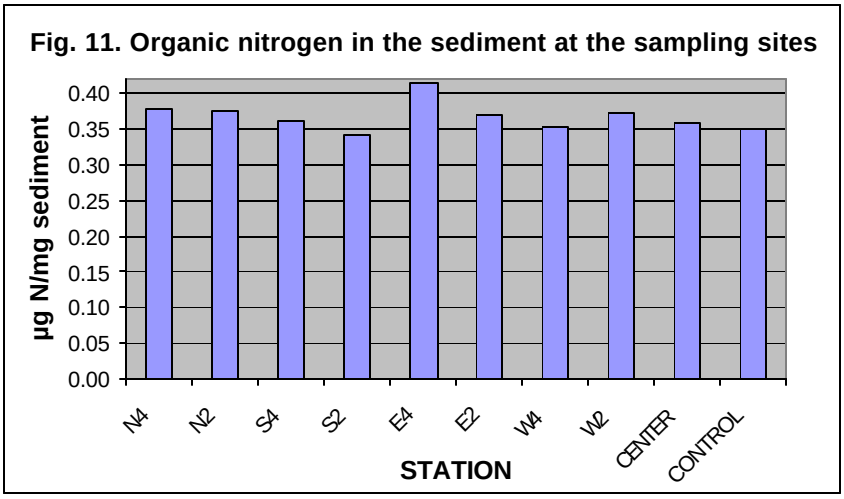


Fig. 11. Organic nitrogen in the sediment at the sampling sites
µg N/mg sediment
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
N4
N2
S4
S2
E4
E2
W4
W2
CENTER
CONTROL
STATION

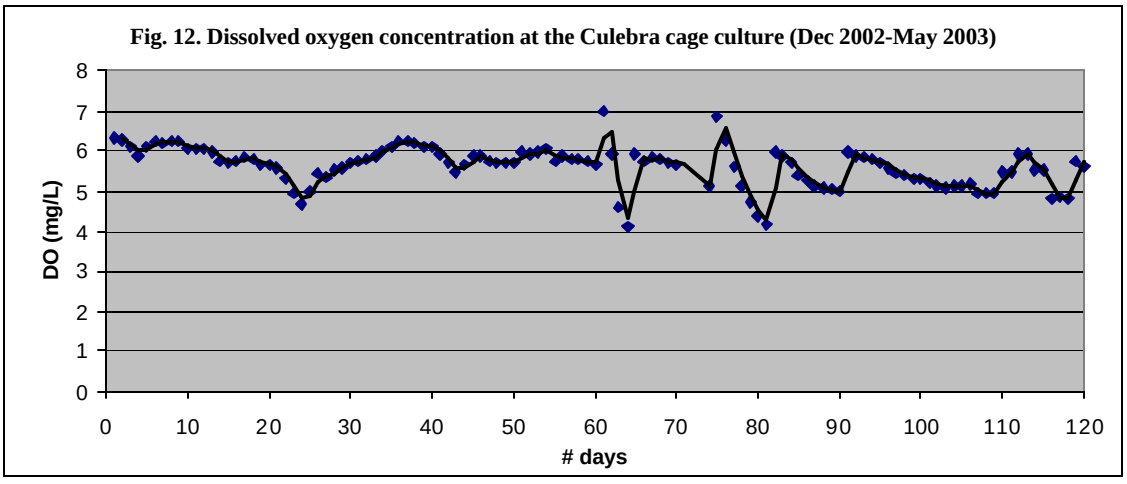


Fig. 12. Dissolved oxygen concentration at the Culebra cage culture (Dec 2002-May 2003)
DO (mg/L)
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
110
120
days

Fig. 13. Water temperature at Culebra cage culture (December 2002- May 2003)

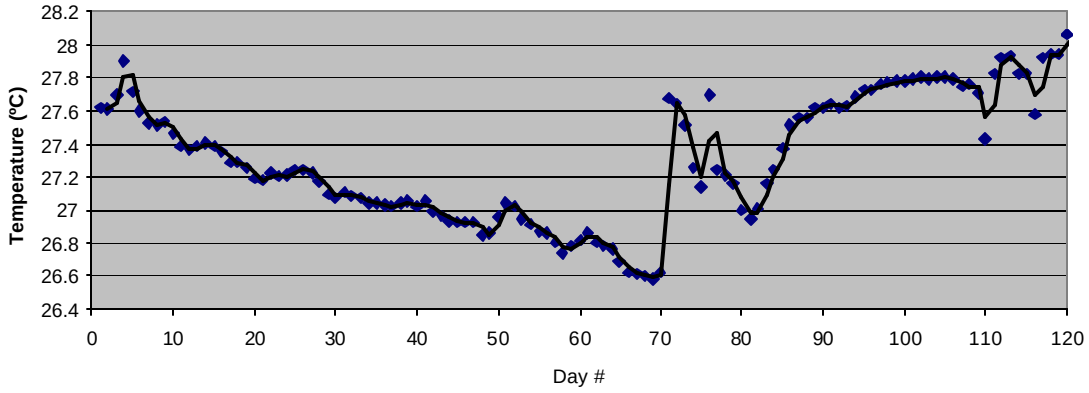


Fig. 14. Chlorophyll-a concentration at Culebra cage culture (December 2002- May 2003)

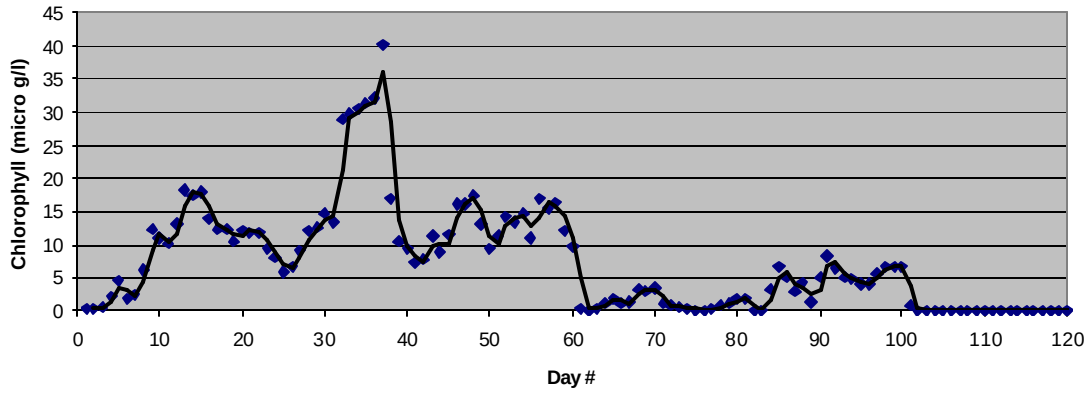
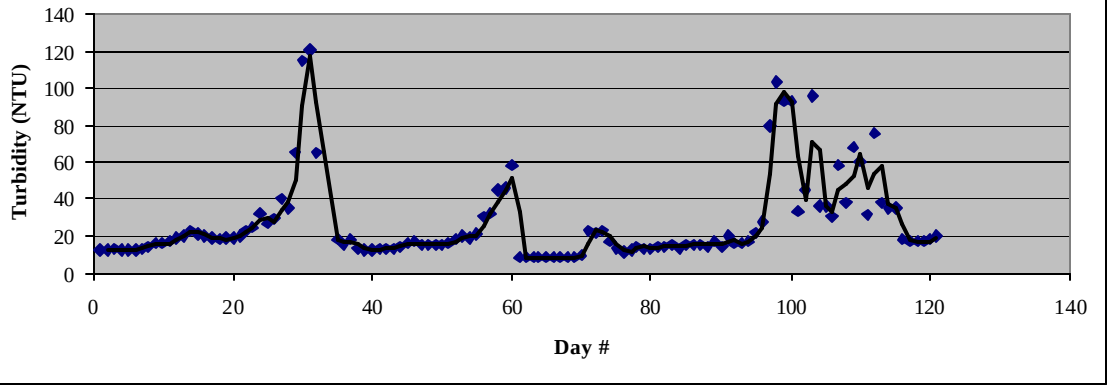
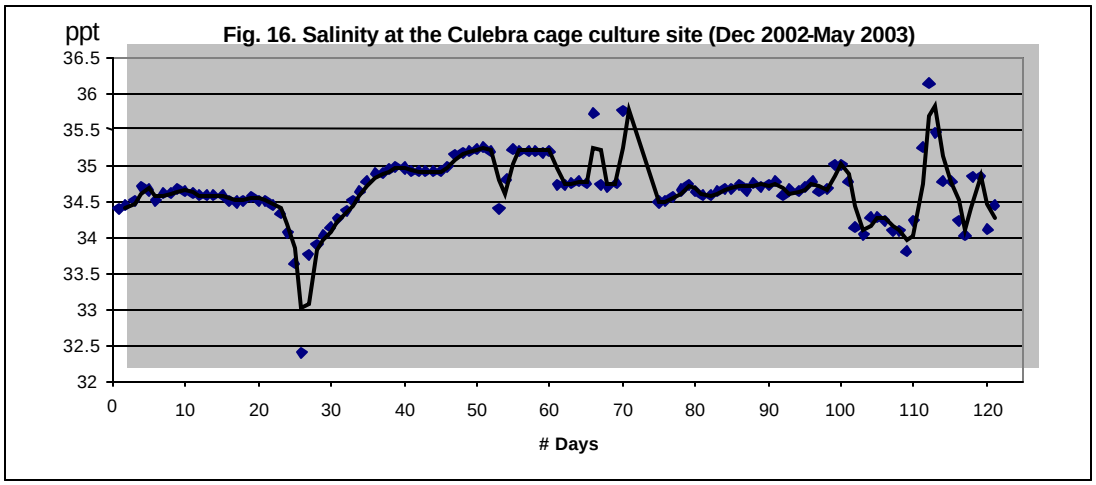


Fig. 15. Turbidity at the Culebra cage culture site (Dec 2002-May 2003




ppt
Fig. 16. Salinity at the Culebra cage culture site (Dec 2002-May 2003)
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
0
10
20
30
40
50
60
70
80
90
100
110
120
Days

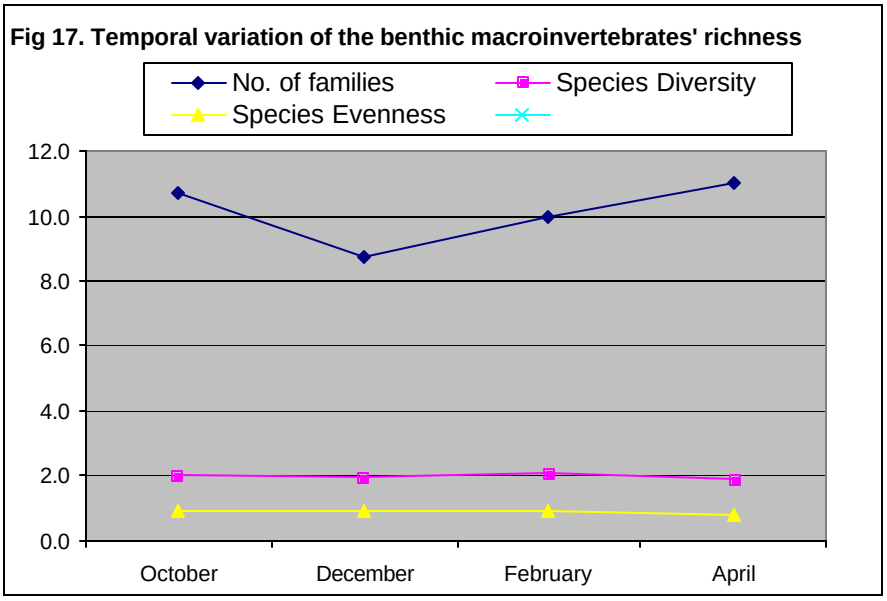


Fig 17. Temporal variation of the benthic macroinvertebrates' richness
No. of families
Species Diversity
Species Evenness
12.0
10.0
8.0
6.0
4.0
2.0
0.0
October
December
February
April

Fig. 18. Species richness of benthic macroinvertebrates at Culebra cages

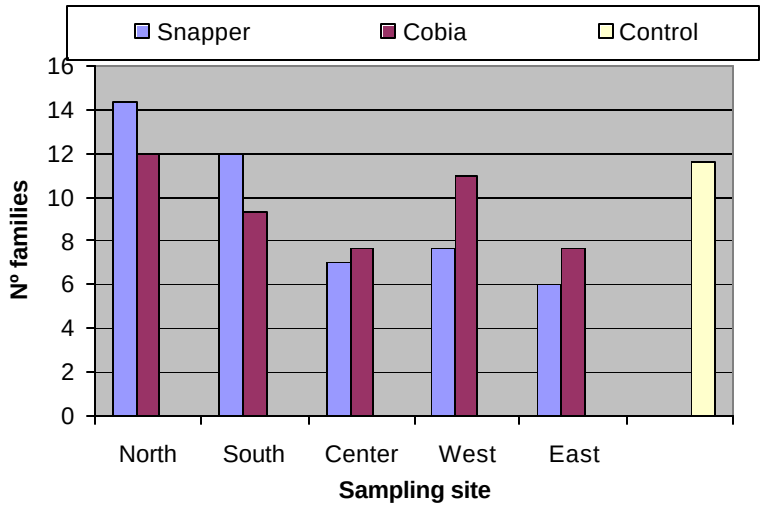
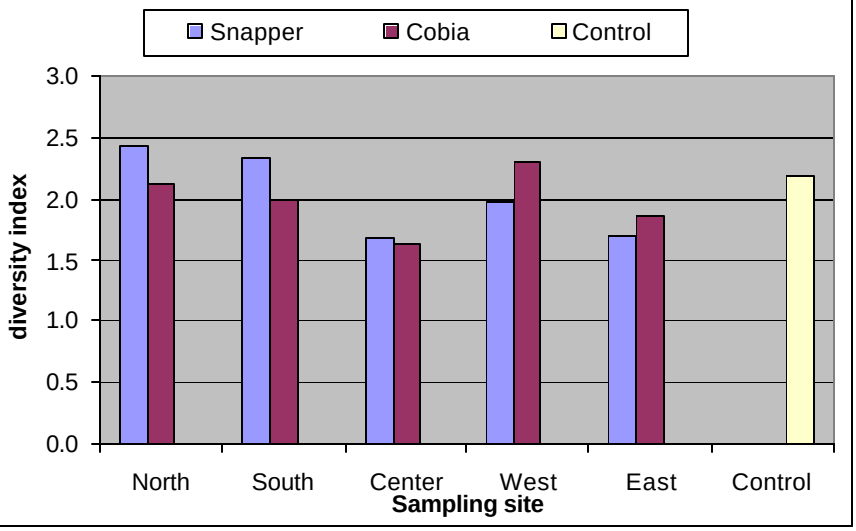


Fig. 19. Shannon diversity index for the benthic macroinvertebrates at Culebra cages



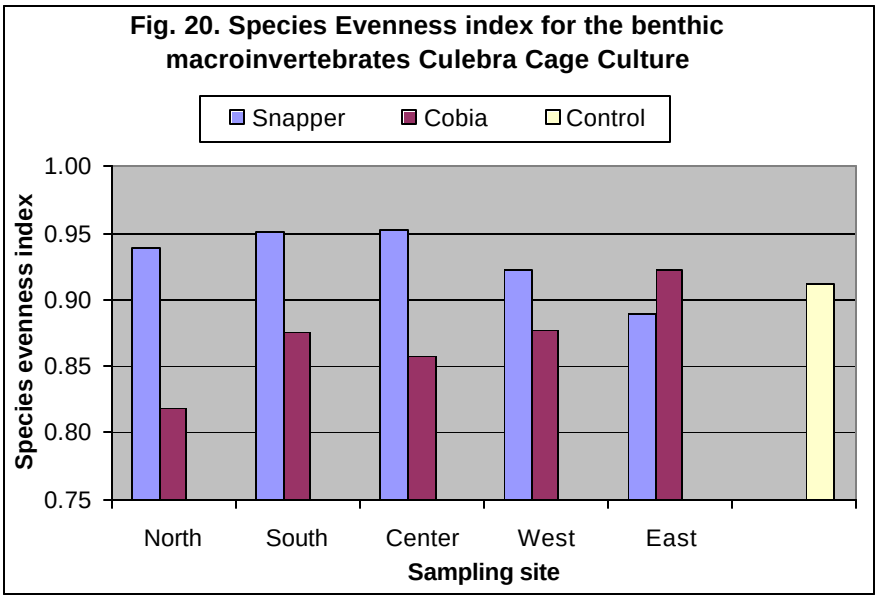


Fig. 21. Fish Family abundance at Culebra Cages culture

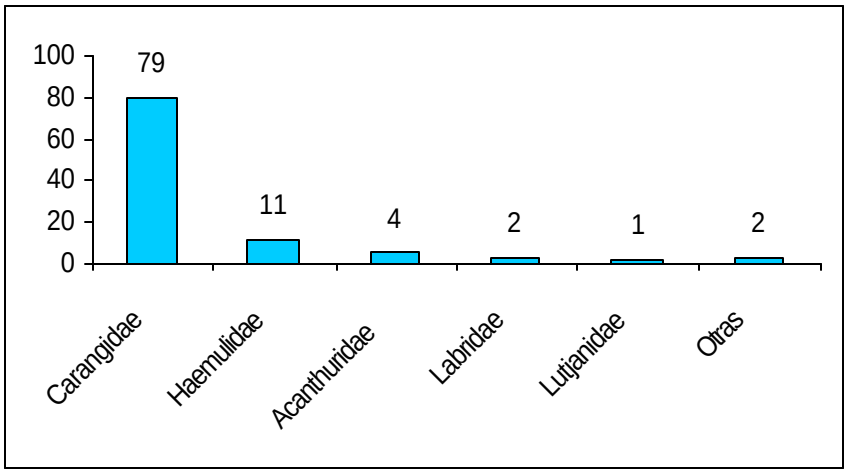


Fig. 22. Average monthly tide currents at Culebra Passage

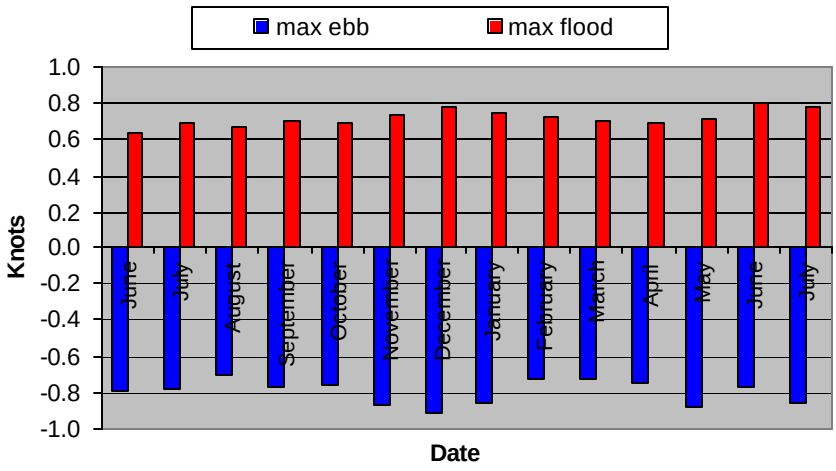


Fig. 23. Average monthly aAir temperature, heat index, and dew point at the Culebra Passage

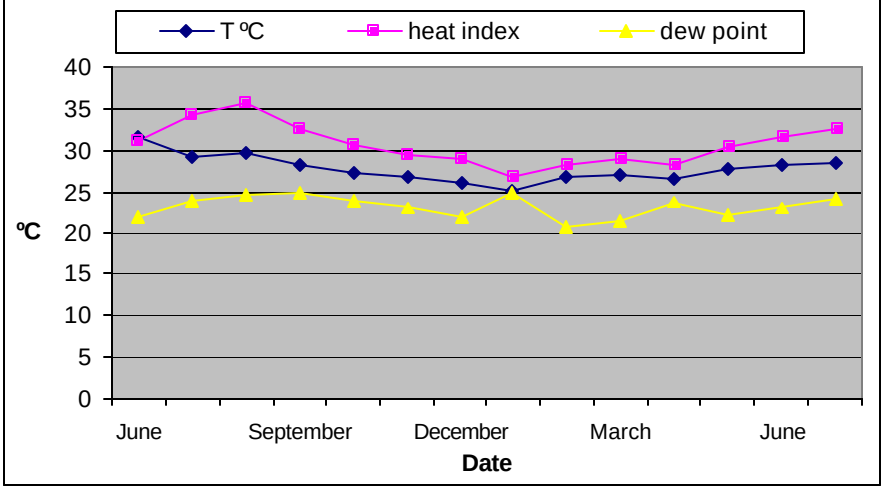


Fig. 24. Average monthly wind velocity at the Culebra Passage

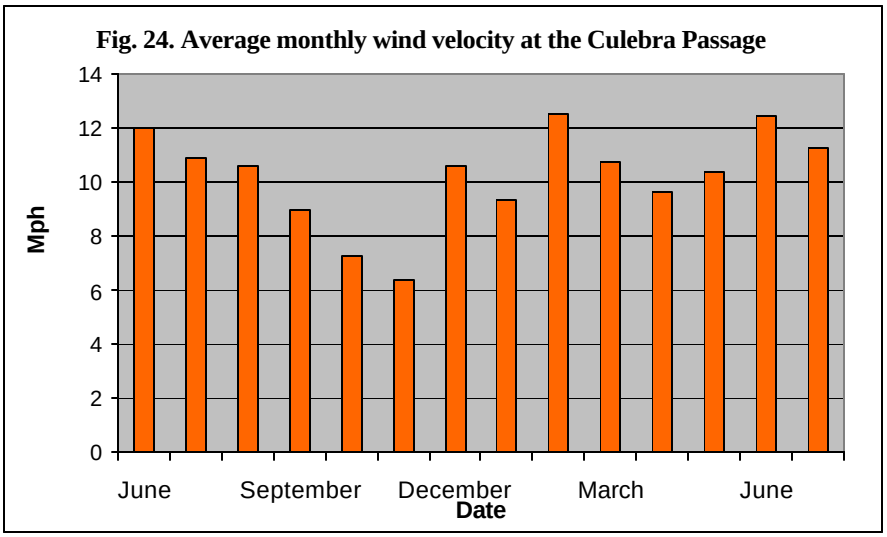


Fig. 25. Average monthly relativy humidity at Culebra Passage

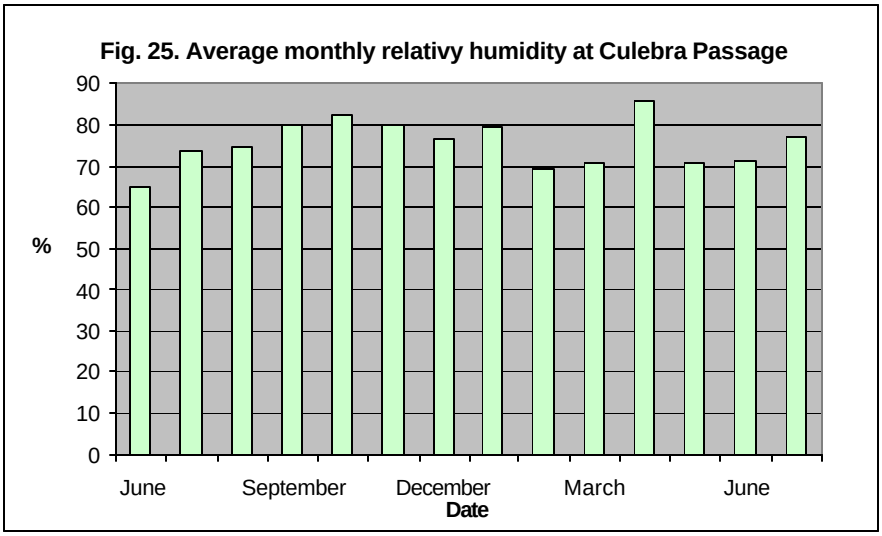


Fig. 26 Average monthly air pressure at Culebra Passage

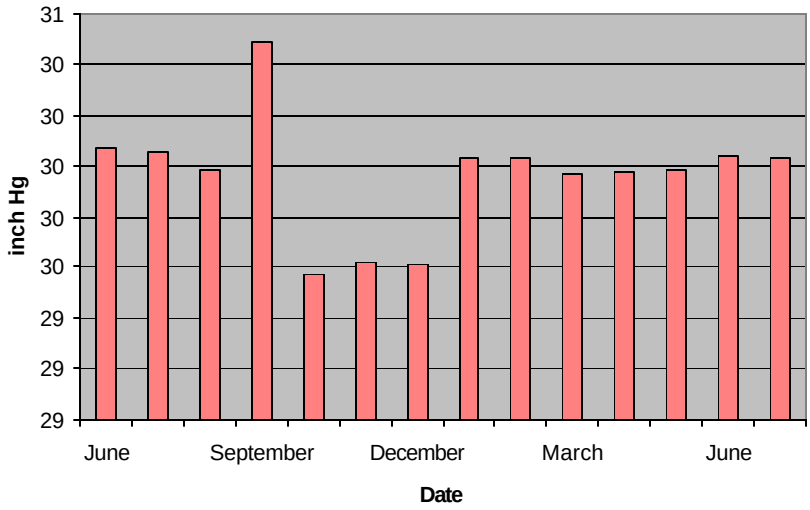


Fig. 27. Culebra Site Location

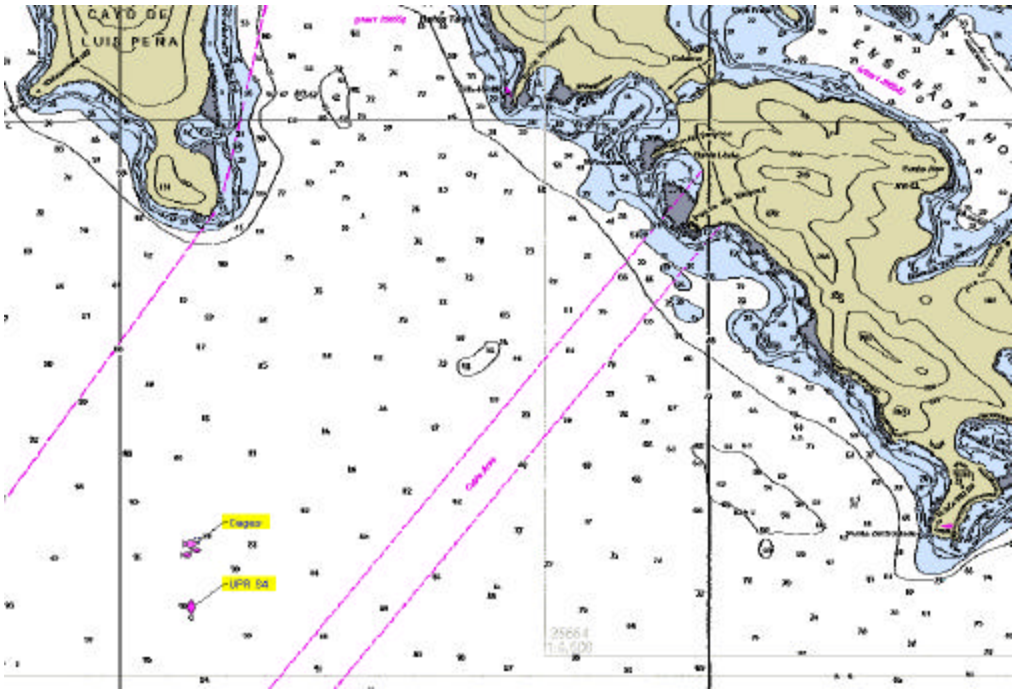


Fig. 28. Culebra 2 flow direction full time series

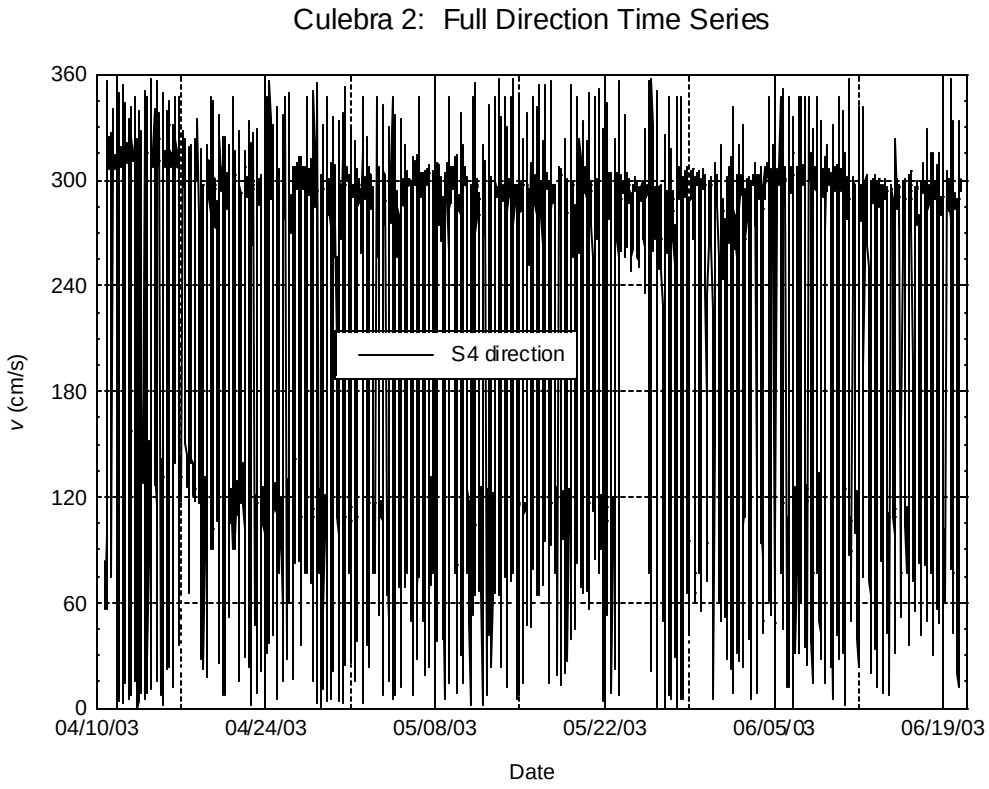


Fig. 29. Culebra 2 flow speed full time series

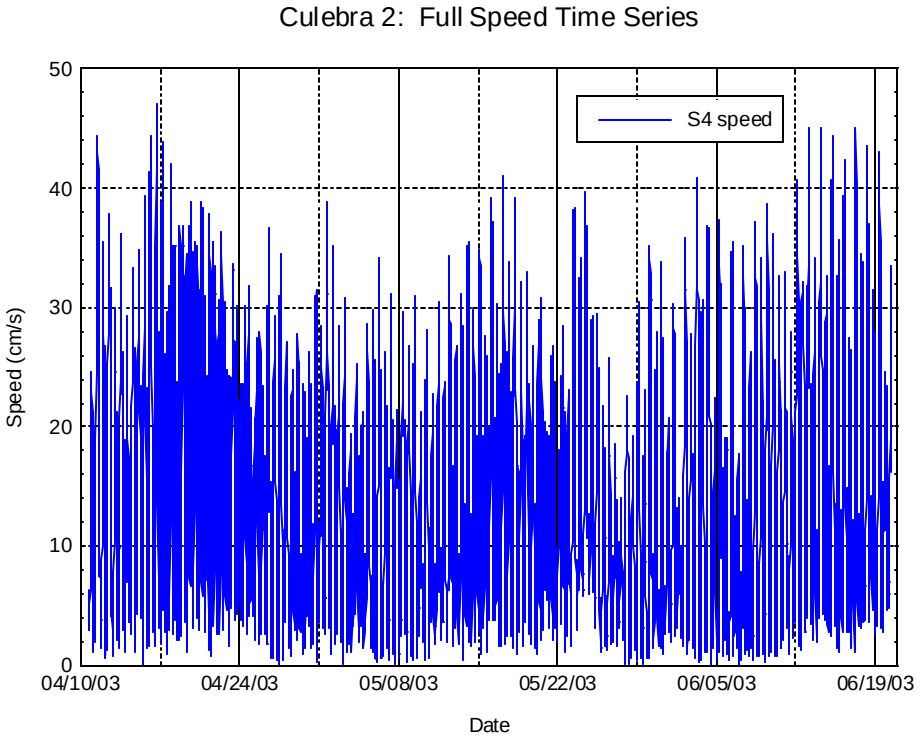


Fig. 30. Culebra 2 rotated *v* full time series. North-south axes rotated by 60° so positive/negative *v* points towards 300°/120° true

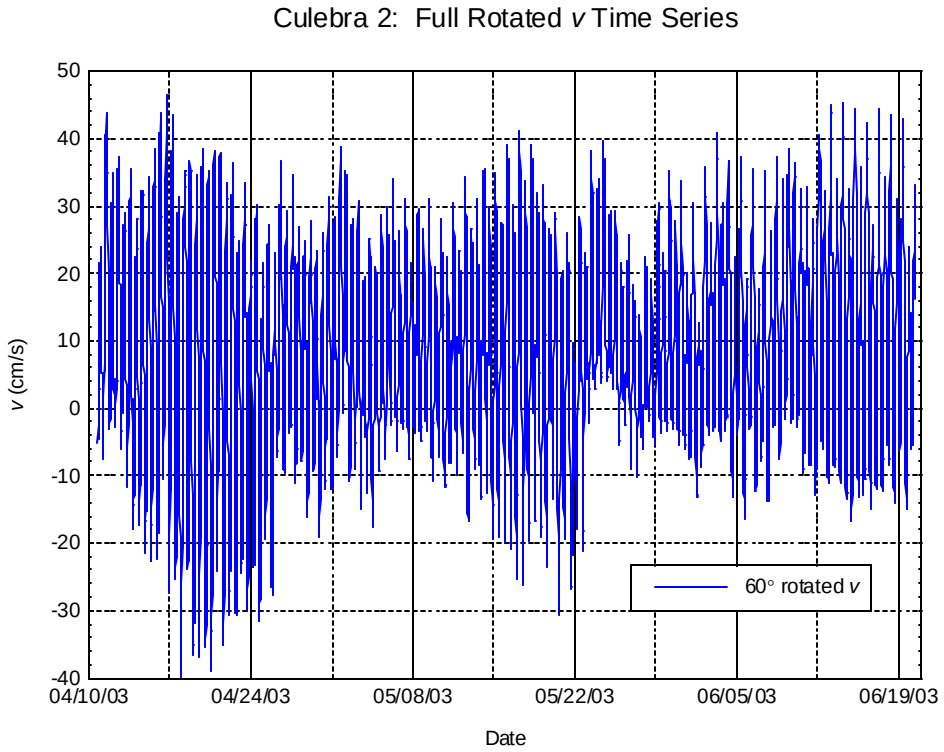


Fig. 31. Culebra 2 rotated *u* full time series. North-south axes rotated by 60° so positive/negative *u* points towards 30°/210° true

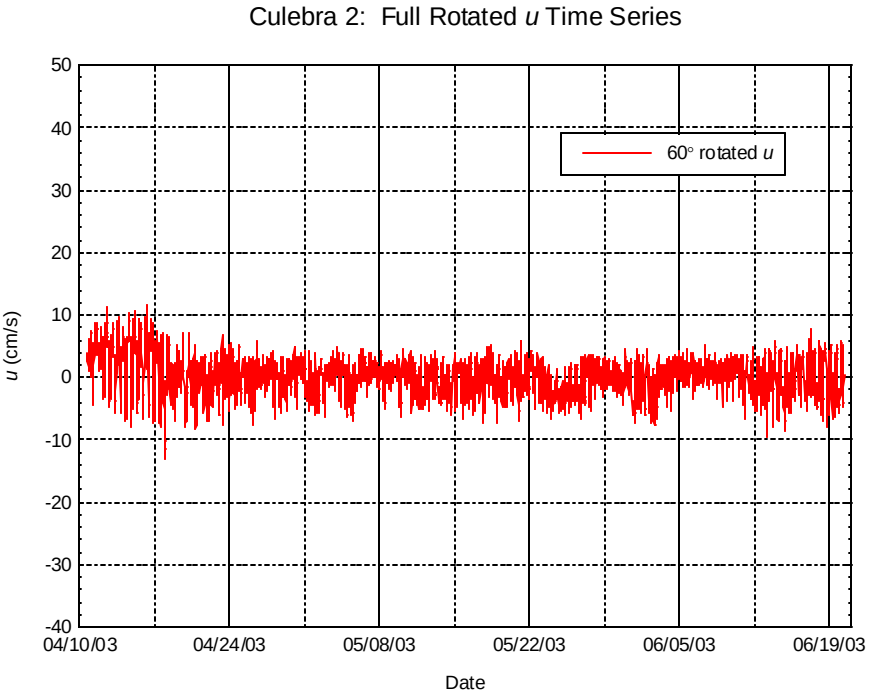


Fig. 32. Culebra 2 full record progressive vector diagram. Markers are spaced on a weekly basis

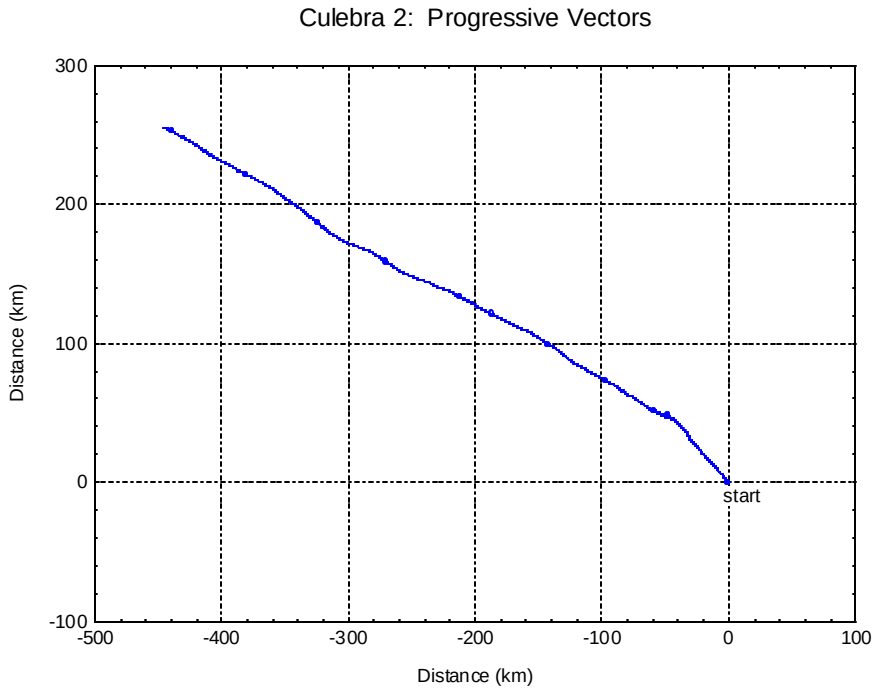


Fig. 33. Culebra 2 current transport rose. The length of each vector represents the percentage of the total transport that lies in any given 15° bin. Each radial divisions indicates 10% of the total transport

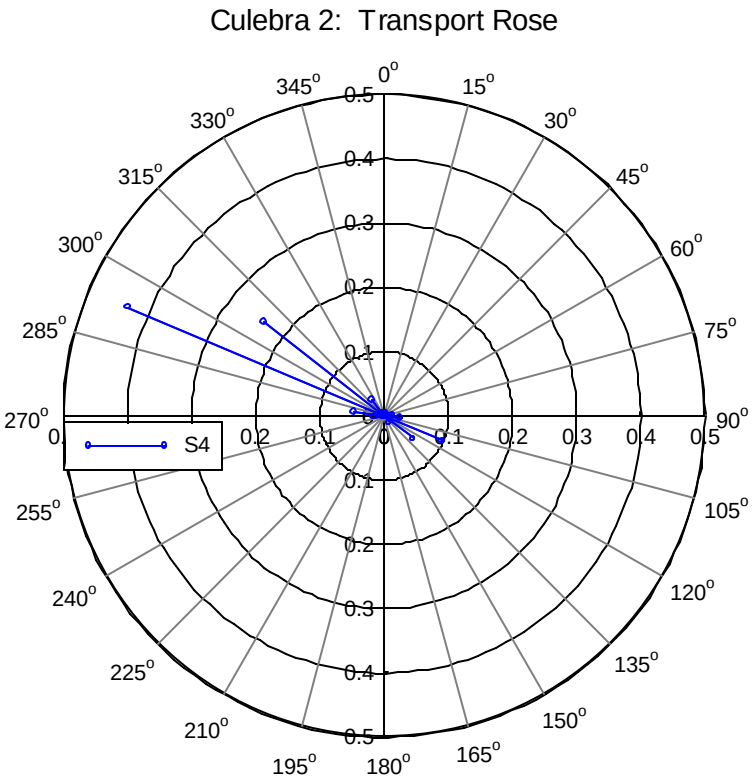


Fig. 34. Predicted tide at Ensenada Honda. Tide predicted with *Tide and Currents* software from Nautical Software, Inc.

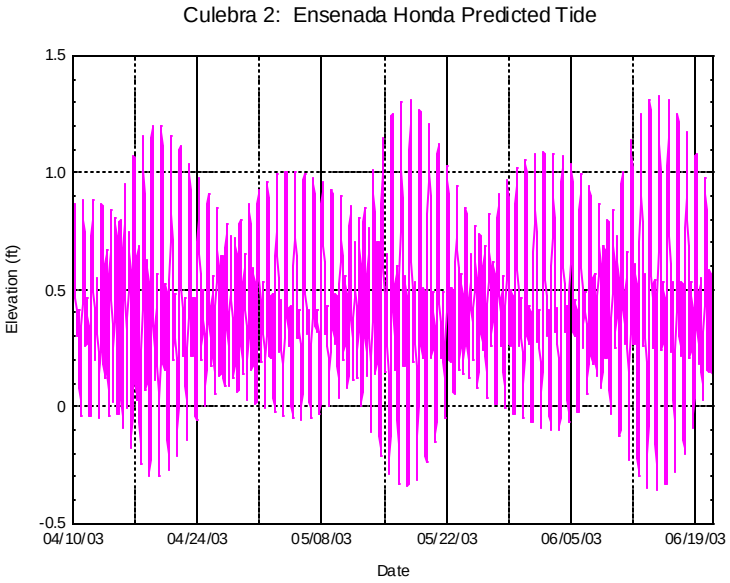


Fig. 35. Culebra 2 flow direction from the S4 and the predicted tide at Ensenada Honda. Tide predicted with *Tide and Currents* software from Nautical Software, Inc.

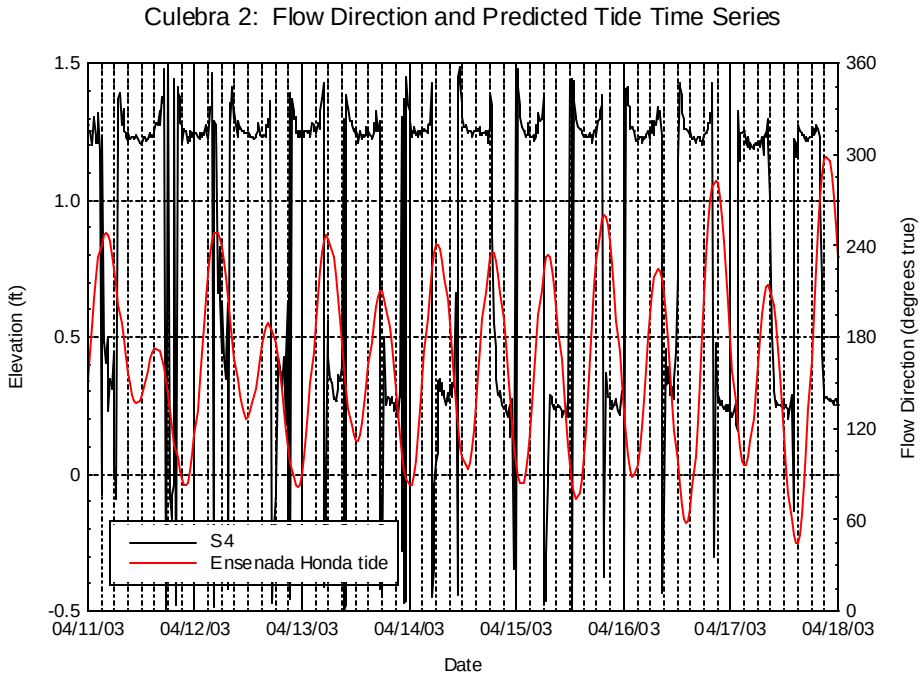


Fig. 36. Culebra 2 rotated *u* and *v* time series. Axis rotation as in Figures 30 and 31.

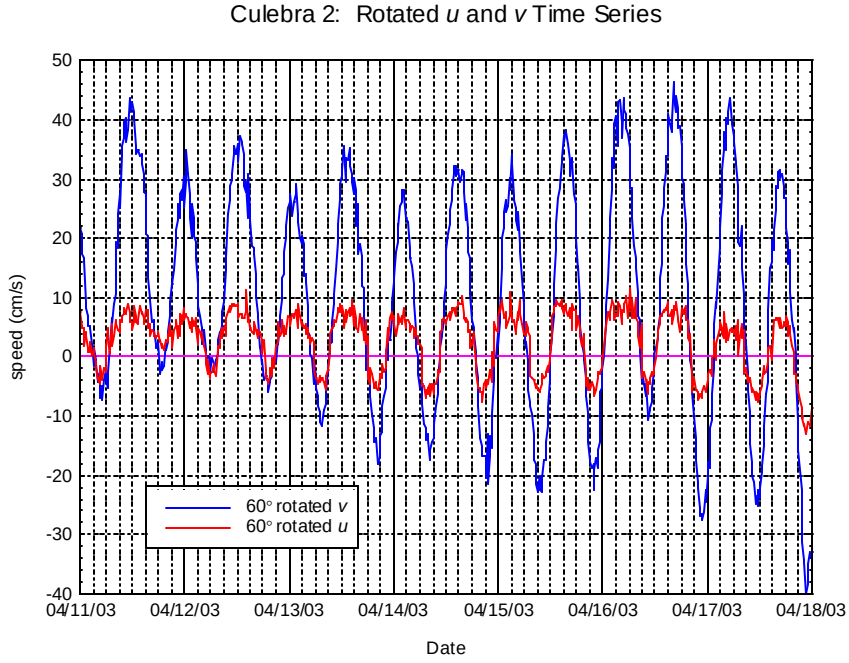


Fig. 37. Culebra 2 progressive vector diagram. Markers are spaced on a daily basis.

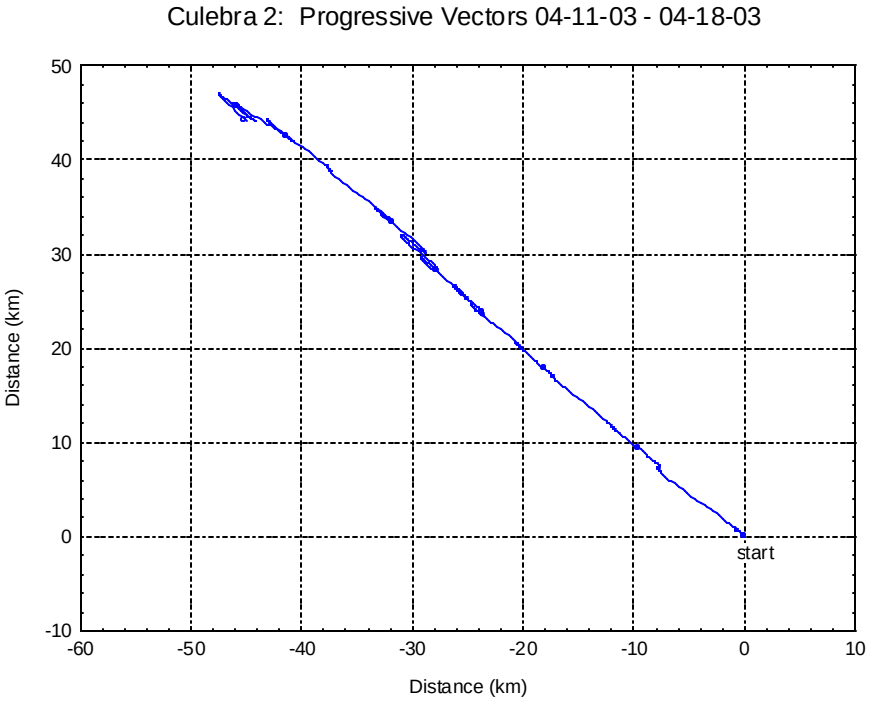


Fig. 38. Culebra 2 flow direction from the S4 and the predicted tide at Ensenada Honda. Tide predicted with *Tide and Currents* software from Nautical Software, Inc.

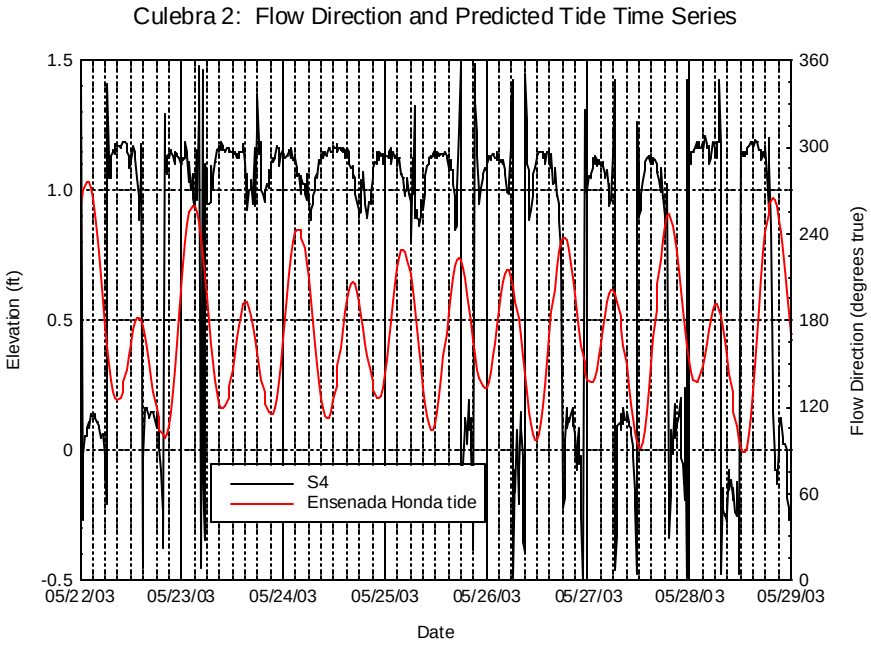


Fig. 39. Culebra 2 rotated *u* and *v* time series. Axis rotation as in Figures 30 and 31

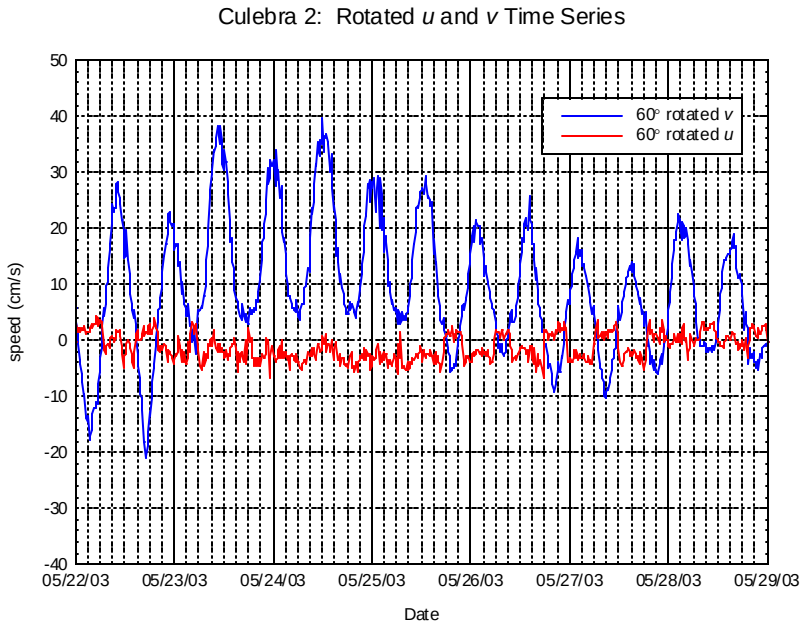


Fig. 40. Culebra 2 progressive vector diagram. Markers are spaced on a daily basis

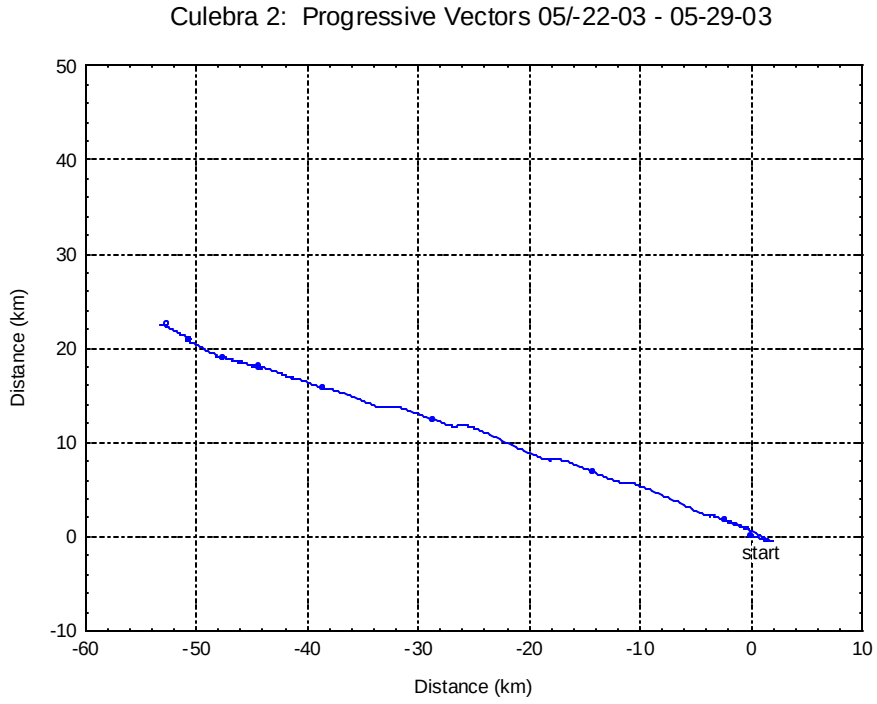


Fig. 41. Culebra 2 Smoothed and rotated *u* and *v* time series. Axis rotation as in Figures 30 and 31

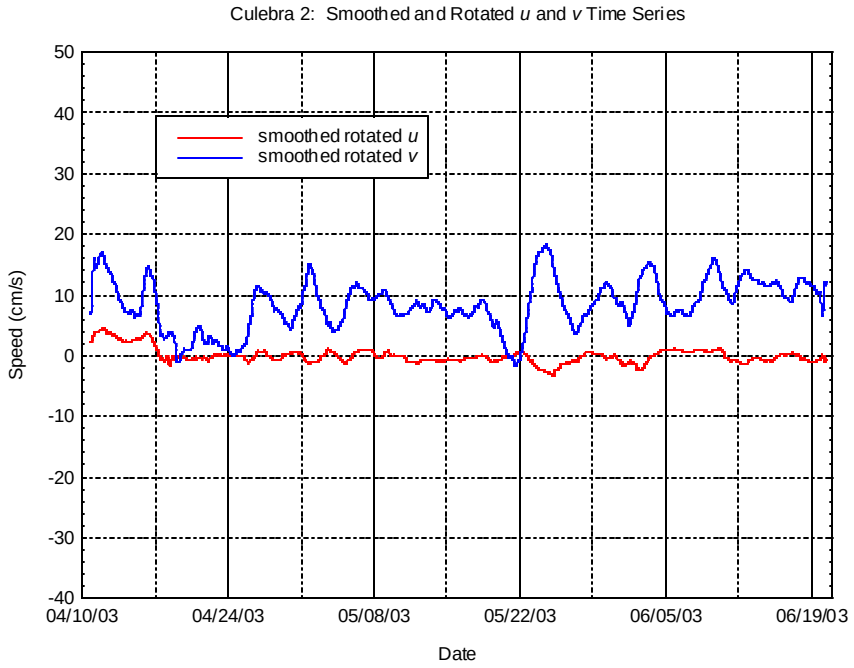


Fig. 42. Progressive vector diagrams for similar time periods in 2002 and 2003. Markers are spaced on a daily basis

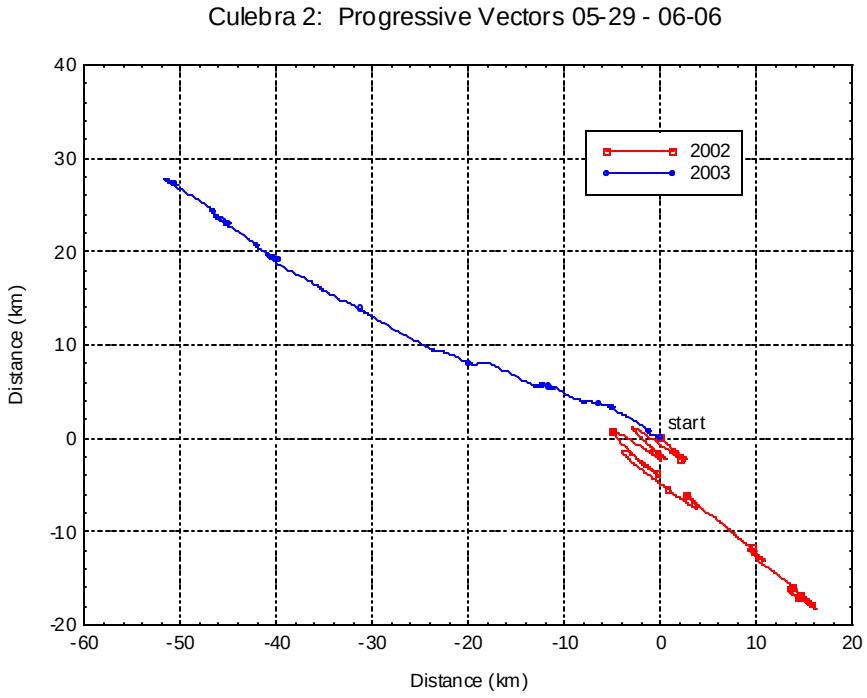


Fig. 43. Culebra 2 power spectral density vs. frequency plot for the rotated *u* time series. Frequency in units of 1/hour

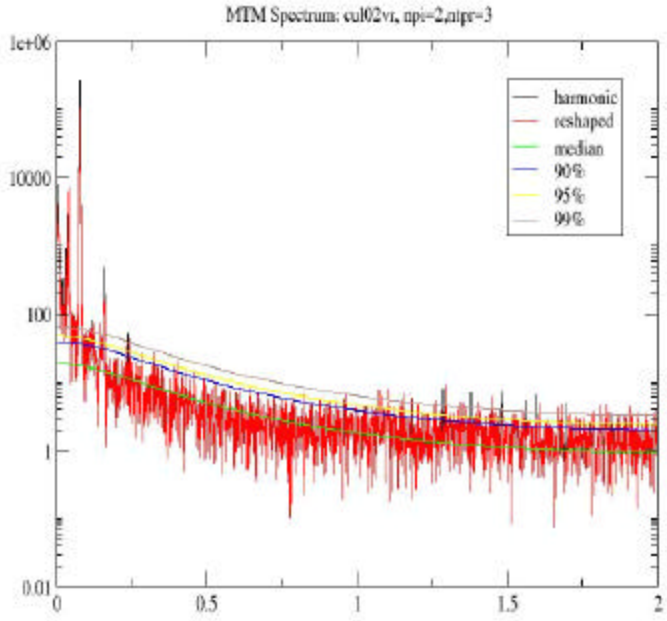


Fig. 44. Culebra 2 power spectral density vs. frequency plot for the rotated *v* time series. Expanded low-frequency section of Figure 17. Frequency in units of 1/hour

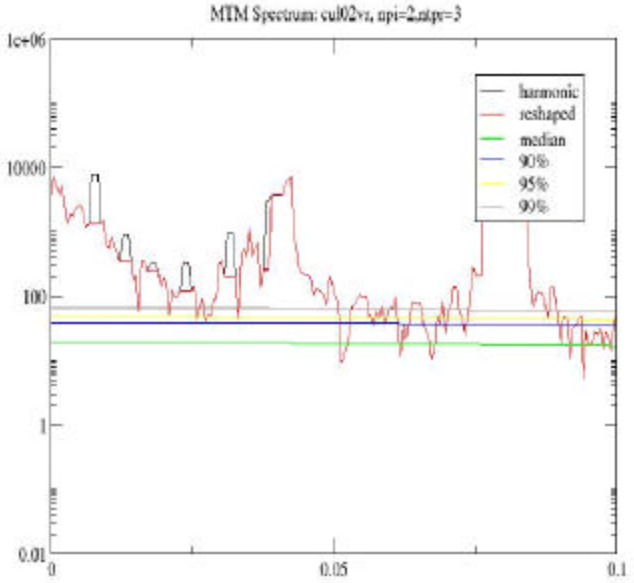


Fig. 45. Culebra 2 power spectral density vs. frequency plot for the rotated *u* time series. Frequency in units of 1/hour

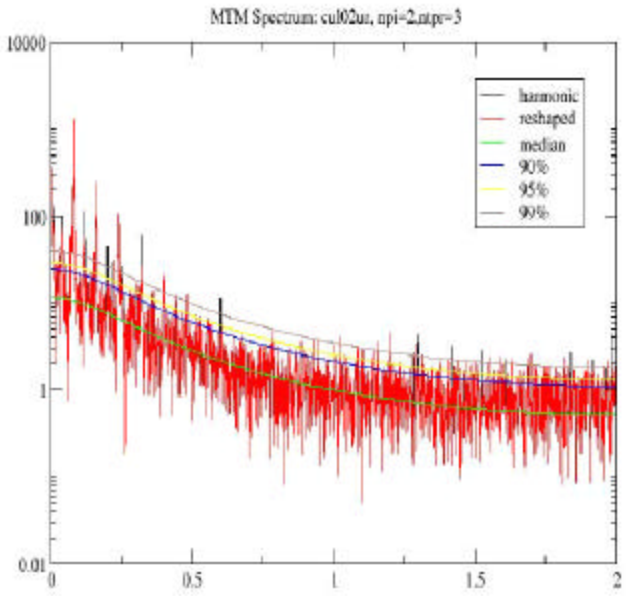


Figure 46. Culebra 2 temperature time series from the S4

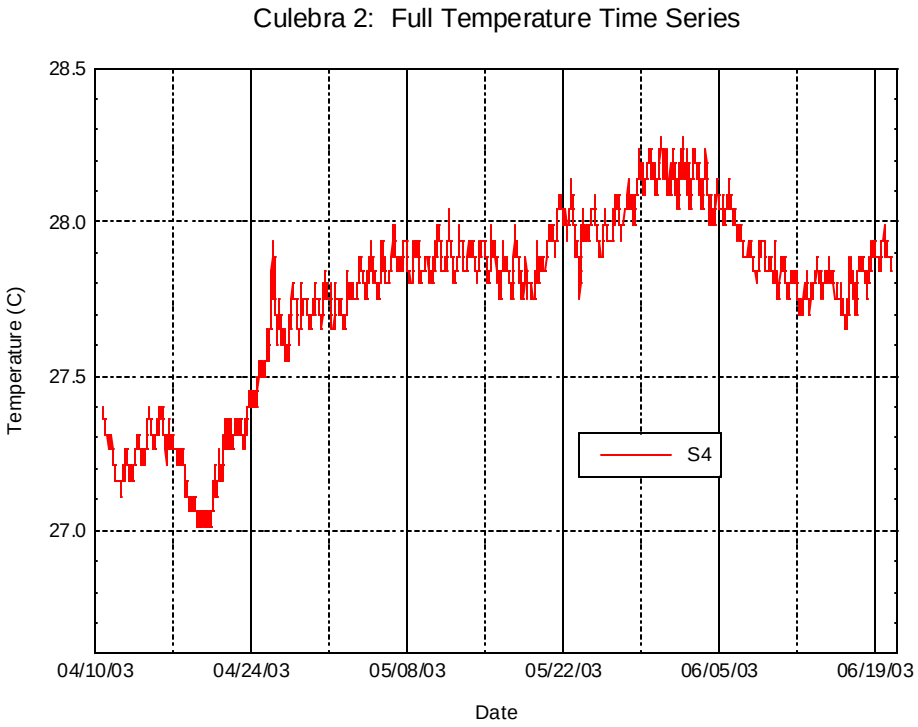
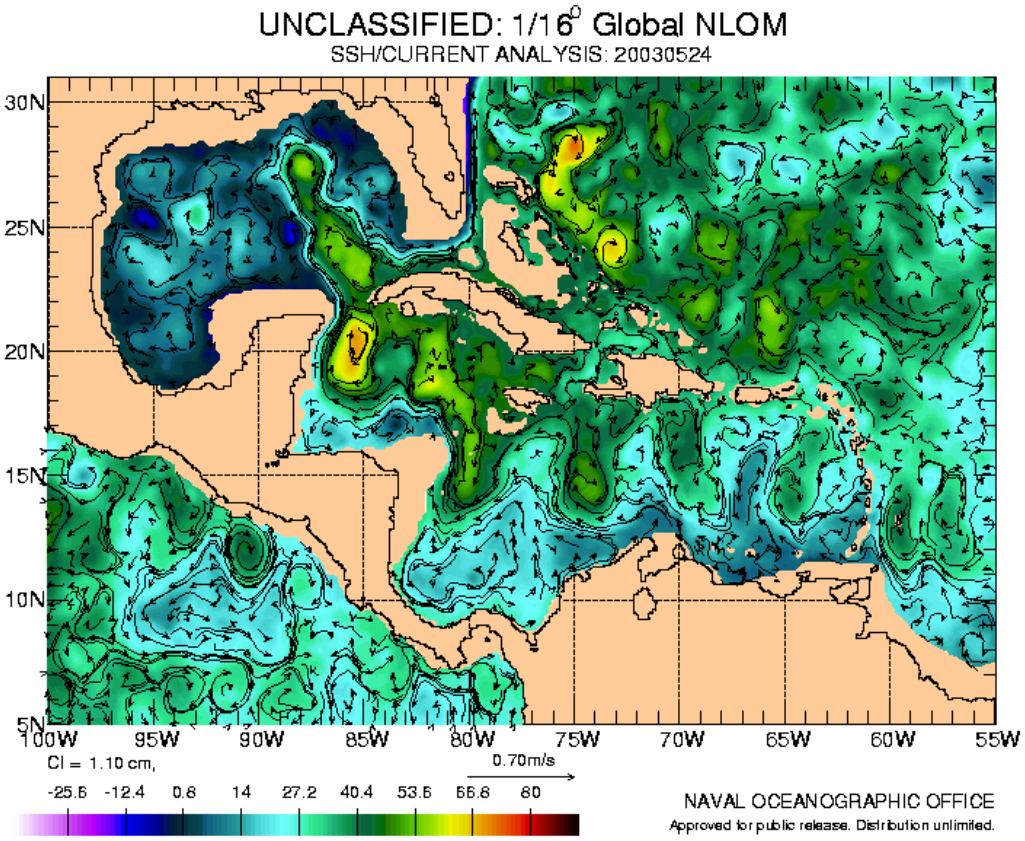


Figure 47. NLOM sea surface height and surface current analysis for May 24, 2003. Image downloaded from http://www7320.nrlssc.navy.mil/global_nlom/globalnlom/ias.html.



Appendix 2-Tables

Table 1: Culebra 2 S4 configuration.

Sampling frequency	2 Hz
Averaging interval	60 s
Cycle interval	15 minutes
S4 depth	14 m
Bottom depth	27 m
Mooring type	taut-wire

Table 2. Mean statistics and percentiles. Depth in meters and speeds in cm/s.

Depth	**Scalar**	**Res**	***u***	***v***	**10**	**50**	**90**	**Max**
14	15.2	8.4	-0.02	8.4	3.2	13.0	30.4	47.0

Table 3. Activities planned for social component of the project.

Months	Task
August to September	**Conduct interviews**
September to October	**Development of the data bank (SPSS-Program)** **Conduct data analysis and interpretation** **Coordinate activity in Culebra to present the final report**
October to November	**Written final report** **Presentation of the main results in Culebra**

Appendix 3-Forms for Social Component of Project

Consent Form (English Version)

PARTICIPANT CONSENT FORM
(Interview)

Hello! I am (*give name*), (Investigator) for the Project entitled "Offshore Cage Culture: Environmental Impact and Perceptions by Local Fishing Community" by Drs. Alexis Cabarcas, Dallas Alston, Daniel Benetti, Janet Bonilla, and Sara Meltzoff, University of Puerto Rico, Mayagüez Campus and the University of Miami using funding from the US National Marine Fisheries Service. Among the studies performed, the researchers would like to ascertain perceptions of the Culebra community relating to new technology utilizing open-ocean cage aquaculture and their relations to various aspects, including economic, environmental, and work issues.

We are inviting you to participate in this study. **Your participation will consist** of one interview that with questions concerning your demographic information (i.e., age, sex, civil status, etc.), information related to your fishing activities (if applicable) and your perception relating to open-ocean cage aquaculture in Culebra.

Your participation in this study is free and voluntary meaning that you are free to participate or not. Even though you may sign this consent form, you may change you mind at any time and withdraw your consent. If the latter case is your decision, please indicate this to the person giving the interview.

The information that you provide during the interview is **anonymous and confidential**. This means that the interviews will not indicate names or information that could be related to your name such as social security number, address, or telephone number. Information you provide will be used only for the purposes of the study. Once you complete the interview, the information will be kept in a locked file in the Center of Social Applied Research (CISA for the Spanish abbreviation) of the University of Puerto Rico, Mayagüez Campus. Only personnel that work in this study will have access to the information you provide.

You will **not receive benefits** by participating in this study. You are not expected to suffer physical or psychological injury by participating in this interview. Nevertheless, if any question causes uneasiness, you may indicate you do not wish to respond. If you feel uneasy, immediately indicate to the investigator that you would like to terminate the interview.

Once the study is completed, you will have access to the **results of the report** by November 2003, which will include a compilation of results of the participants of the interview process. This will also assure your information will remain confidential.

If you have any doubts concerning the study, the investigator can clarify them now or at any time you wish. If you are not satisfied with the information offered or if you have any other comments please tell the investigator or contact the following person responsible for the social component of the study:

Dr. Janet Bonilla, Assistant Professor
University of Puerto Rico, Mayagüez Campus
Department of Social Sciences
PO Box 9266
Mayagüez, PR 00981
Tel. 1(787) 832-4040 Ext. 2108, 2109
You may leave a voice message at extension 3839 or 3303

PARTICIPATION CLAUSE

"I have answered all of the questions of this study to my satisfaction. I understand that a copy of this form of consent was given to me. My signature in this form indicates that I, of legal age and resident in Culebra, PR, understand the information presented, and that I am willing to voluntarily participate in the study. "

_____

Signature or Initials of the Participant/Date

_____

Signature of the Investigator/Date

_____

Signature of the Social Component Investigator/Date

Interview for the General Population

STUDY OF GENERAL KNOWLEDGE AND PERCEPTION OF CULEBRA, PUERTO RICO, FISHERMEN AND GENERAL COMMUNITY IN RELATION TO THE OPEN-OCEAN AQUACULTURE PROJECT

Interview to members of the General Community

Part I: Socio-demographic variables

I will ask to you questions concerning socio-demographic aspects. For each question, you should answer or select the description which most closely describes you.

1. What is your sex?	_____ feminine _____ masculine
2. How old are you?	_____ years
3. What is your civil status?	_____ single _____ married _____ co-inhabiting without being legally married _____ separated (widow, divorced)
4. How many people live in your home? (Include yourself.)	_____ number of people
5. Of these people, how many are relatives of yours?	_____ all _____ only some how many? _____
6. Do you have children?	_____ yes how many? _____ _____ no
7. Have you lived all of your life in Culebra?	_____ yes _____ no in what town, state or country have you lived? _____ how many years have you lived in Culebra? _____
8. Your work is:	____ part-time ____ full-time
9. Your work is?	_____ in a public agency (local or federal government) _____ in a private enterprise indicate enterprise: _____ _____ own business _____ other (specify) _____
10. What is you title or position in this work?	_____ (title or position)
11. In what town municipality) do you work?	_____ Culebra _____ another town (indicate which) _____
12. In addition of the work mentioned above, do you work in one of the following activities?	_____ fisheries _____ agriculture _____ construction _____ mechanics _____ electricity _____ other (specify)
13. Do you receive pay from these activities?	_____ yes _____ no

14. Which of the following categories best describes the monthly income of your family?	_____ less than $4,999 _____ $5,000 a $9,999 _____ $10,000 to $14,999 _____ $15,000 to $19,999 _____ $20,000 to $24,999 _____ $25,000 to $34,999 _____ $35,000 to $44,999 _____ $45,000 or more
15. How many people contribute to this income?	_____ number of people
16. Does your family receive some type of governmental economic aid?	_____ yes _____ no
20. Which of the following did you complete?	_____ elementary school _____ intermediate school _____ superior school _____ university _____ none of the previous options _____ I did not attend school

Part II: Description of your work as a fisherman

Now I am going to ask to you questions concerning your work as a fisherman.

21. Why do you fish?	
22. How many days (average) do you fish each week?	_____ days
23. At what time do you go fishing?	_____ hora
24. Which type of fishing do you do mostly?	_____ More frequent
25. What do you do with the capture of fish and seafood?	(indicate all that apply) _____ sell fish to the of Fishermen's Association _____ sell to a refrigeration service _____ sell to a restaurant _____ sell to a residence _____ sell in the street _____ give catch to friends and relatives _____ process fish into fried products to be sold _____ use for family consumption _____ other (specify): _____

Part III. Knowledge of the methods and the open-ocean cage aquaculture project

Now I will ask to you how much you know about diverse aspects of the open-ocean cage aquaculture project in Culebra, as well as aquaculture in general.

26. Have you heard of the open-ocean aquaculture project here in Culebra? 22. How did you learn about the project?	____ yes ____ no **(*Proceed to the question # 30)***

	nothing	something	a lot
28. How much do you know about the project?			
29. Explain to me what you know concerning the project?			
	nothing	something	a lot
30. How much do you know of the company, Snapperfarm, Inc.?			

31. Explain to me what you know concerning Snapperfarm.		
32. How did you learn about Snapperfarm?		
Do you know...	Yes	No
33. The **advantages of open-ocean cage aquaculture** as a technique to **produce** fish or other marine species		
34. Explain what you consider are advantages?		
35. The **disadvantages or limitations of open-ocean cage aquaculture** as a technique to **produce** fish or other marine species	Yes	No
36. Explain what you consider are disadvantages?		
37. The impact of **open-ocean cage aquaculture** on Culebra's environment	Yes	No
38. Explain to me what you know concerning the environmental impact		
39. The impact of **open-ocean cage aquaculture** in reference to Culebra's economy	Yes	No

40. Explain to me what you know concerning the economic impact		
41. The impact of open-ocean cage aquaculture on Culebra's fishing	Yes	No
Explain to me the impact on fishing		
42. Impact of open-ocean cage aquaculture on the fishermen of Culebra	Yes	No
43. Explain to me the impact in the Culebra fishermen		
44. The impact of open-ocean cage aquaculture in relation to the Culebra community	Yes	No
45. Tell me what you think.		
46. The skills or knowledge needed to manage open-ocean cage aquaculture	Yes	No
47. What are these skills or knowledge?		
48. The approximate cost of the production of fish or other seafood (shrimps, lobsters) using open-ocean cage aquaculture.	Yes	NO
49. Which would estimate are the cost? Cost of the cages: _____ Other costs: _____ Total cost: _____		

Would you like to know more concerning the Culebra open-ocean aquaculture project?			Yes	No
51. How much it would like to know:	Little	Something	A lot	Everything
Of what aspects in particular would you like to know more?				

Part IV. Attitudes concerning the use of open-ocean aquaculture techniques

Finally, I will ask your opinion on the use of open-ocean aquaculture techniques to produce and harvest fish.

52. Are you in agreement or not with the use of open-ocean cage aquaculture in Culebra to produce fish or other seafood? In agreement _____ Do not agree _____
53. Why are you in _____(agreement or not in agreement)?
54. Are you to favor or against the use of open-ocean cage aquaculture in another place to produce fish or other seafood?
55. Why are you in favor or against?
56. Are you disposed to learn skills needed to produce fish or other seafood using this technology? Yes _____ No _____
57. Why?
58. Are you disposed to integrate or to complement your fishing activities with the aquaculture techniques?