PN-AAZ-368

54926

Working Paper Series

Working Paper No. 10

"The Use of Stationary Hydroacoustic Transducers to Study Diel and Tidal Influences on Fish Behavior

by

Richard E. Thorne, University of Washington
John Hedgepeth, University of Washington
Jorge Campos, University of Costa Rica
School of Fisheries
University of Washington

October, 1987

Fisheries Stock Assessment
Title XII
Collaborative Research Support Program

The Fisheries Stock Assessment CRSP (sponsored in part by USAID Grant No. DAN-4146-G-SS-5071-00) is intended to support collaborative research between U.S. and developing countries' universities and institutions on fisheries stock assessment and management strategies.

This Working Paper has been produced by the collaborative efforts of The University of Washington and The University of Costa Rica-Centro de Investigacion en Ciencias del Mar y Limnologia (CIMAR) in association with The University of Delaware. Additional copies are available from the CRSP Management Office and from:

Dr. Vincent Gallucci
Center for Quantitative Science HR-20
School of Fisheries
University of Washington
3737 15th Avenue, N.E., Room 304
Seattle, Washington 98195

## Abstract*

Diel and tidal conditions are two important factors that influence fish behavior. Many fisheries, such as the Corvina fishery in the Gulf of Nicoya, Costa Rica, take advantage of these influences. Study of the fish behavior in the Gulf of Nicoya is complicated by the shallow water and near boundary distribution of fish. This problem was overcome by the application of stationary transducer arrays, including both vertical and slant angle orientation. This allowed complete coverage of the water column while also measuring the velocity of fish movement. Data collected during February 1987 showed strong diel and tidal influences on fish behavior. The information obtained from this application will provide insight into the efficiencies of the gill nets used in the fishery as well as independent estimates of the fish abundance.

*This paper was presented at the International Symposium on Fisheries Acoustics, June 22-26, 1987, Seattle, Washington, USA.

## Resumen

Muchas pesquerias, como la de corvina del Golfo de Nicoya, Costa Rica, aprovechan la influencia de los ciclos diarios y mareales sobre el comportamiento de los peces. La aplicacion de metodos acusticos para estudiar el comportamiento de los peces de aquas someras del Golfo de Nicoya, presenta complicaciones pues se encuentran localizados en las proximidades del fondo y de la superficie. Para solucionar este problema se empleo un conjunto de transductores estacionarios con orientaciones verticales y oblicua. Este equipo proporciona una total covertura de la columna de aqua, ademas de medidas de la velocidad del movimiento de los peces. Los datos obtenidos durante febrero de 1987 indican que las mareas y ritmos diarios ejercen efectos importantes sobre el comportamiento de los peces. Asimismo, la informacion obtenida favorece la mejor comprension del funcionamiento de las redes de enmalle empleadas en la pesqueria y proporciona estimaciones independientes de la abundancia de los peces.


## INTRODUCTION

The management of fisheries usually requires information on the abundance of the stocks under exploitation. In many cases, this information is derived from analysis of the fishery catch records. This approach is cost effective in that the primary sampling effort is conducted by the fishery itself. However, this sampling effort is governed by social and economic factors, rather than scientific or statistical principles. Consequently, interpretation of the data often requires assumptions whose validity is difficult to evaluate. The use of fishery catch records to manage artisanal fisheries is further complicated by diverse landing locations, sustenance fishing, great variety of fishing vessels and gear types, and complex species assemblages.

An alternate approach to stock assessment is direct measurement by fishery scientists. This approach allows application of statistical principles of survey design and measurement techniques that can be standardized and whose biases are better understood. However, cost considerations force a much smaller sampling effort than is available from a commercial fishery. Consequently, it is important that the measurement technique have high sampling power and low operational cost.

These requirements have led to increased use of hydroacoustic assessment techniques (Thorne 1983a, 1983b). The capability of sonar to readily penetrate water and detect the presence or absence of fish has allowed the development of quantitative assessment techniques with high sampling power. However, these hydroacoustic techniques are subject to limitations caused by fish location near boundaries and poor species resolution. In artisanal fisheries, these problems are often compounded by shallow water environments, greater species diversity and more stringent cost considerations (Thorne 1979).

The purpose of the study described in this report was to begin development and evaluation of hydroacoustic techniques for assessment of the corvina stocks in the Gulf of Nicoya, Costa Rica. In addition to shallow water and mixed species, this estuarine environment is characterized by strong tidal currents. Under these circumstances, application of hydroacoustic techniques requires information on the factors that affect the availability of fish to various hydroacoustic deployments and on trends in behavior which might be keys to species identification. Our objective was to obtain initial data on diel and tidal effects on the fish distribution, abundance and behavior.

## MATERIALS AND METHODS

### Location and Transducer Deployment

The study was conducted during February 1987. A stationary transducer deployment was used in order to investigate the vertical distribution of fish throughout the entire water column (Thorne 1980). Data were collected at anchor station for 24 hours at each of two locations: one just east of Islas Cortezas and the second at the south end of Isla Chira (Fig. 1). Three transducers were used. Two were bottom mounted, one vertically oriented and the other oriented at slant angle parallel to the tidal current. The mounting arrangement for these two transducers is illustrated in Fig. 2. The mount was lowered to the bottom. Then the direction of the slant angle orientation was checked and adjusted by divers. The third transducer was oriented vertically downward from the anchored research vessel (Fig. 3). The depth at the Islas Cortezas station varied from 4.7 to 7.4m. The depth at the Isla Chira station varied from 2.3 to 5.3m.

## Digital Acoustic Data Acquisition

The echosounder was a Simrad EY-M. Data were collected sequentially through each transducer, with all three sampled within each one-hour period. The fish targets were recorded on dry echogram paper. Gain and threshold levels for the chart recorder were set to detect a minimum target of about -50dB on the vertically oriented transducers. The slant angle transducer was less sensitive, but was used for directional information only. The echogram depth scale and paper speed were frequently checked by oscilloscope and time marks.

Primary echogram data were converted into digital form using a Summagraphics Summasketch digitizing tablet connected through a serial interface to an IBM-PC compatible microcomputer. This digitizing tablet consisted of two main parts, the stylus and the tablet. A grid inside the tablet sensed the location of the stylus's low intensity magnetic field. In the point mode, the tablet issued one report when either the stylus tip or the stylus side button were pressed. This report consisted of 5 bytes, of which the first byte was identification and the subsequent bytes gave the coordinate data.

A fortran program was written to work with the Summasketch digitizing tablet, and this program provided the foundation for data analysis. The following echogram information was stored on an IBM-PC compatible disk file:
1) minutes from start of study to target initial contact,
2) Duration of target in beam in seconds,
3) range of target initial contact in meters,
4) change in range of the target, and
5) range to bottom or surface.

Microcomputer disk files recorded data from the two locations in the Gulf of Nicoya. These files consisted of data collected in the three deployment modes. Therefore, there was a file for each orientation at Islas Cortezas and at Isla Chira, making a total of six data files. Subsequent graphical and statistical anaysis made use of the digitized echogram data contained in these files.

## Tidal and Diel Recordings

Water current velocities were measured at the surface and near the bottom at approximately hourly intervals throughout the study. A modified Swoffer model 2100 optical current meter gave direction as well as speed. Directional information was used to infer either ebb or flood. Two methods were used to compute tidal current speeds at times in between recordings. Current measurements at Islas Cortezas were fit by sine curves using SPSS nonlinear least squares algorithym (anon. 1985) on the University of Washington Cyber computer. Currents were calculated by linear interpolation at Isla Chira.

A "night index" was computed to give a measure of the altitude of the sun. This index was a simple linear calculation based on time where 1200 (noon) equals 0, and 2400 (midnight) equals 1. Thus one-half would represent either dawn or dusk. This corresponded well with the actual times for sunrise (0620) and sunset (1809) on February 17-19 (Nautical Almanac for 1987). The night index was used to investigate diel correlations with abundance of fish.

## Graphical and Statistical Procedures

Microcomputer programs were written to summarize abundance data by time interval and by water column interval. The time intervals used were the actual intervals of continuous recording in each of the modes of transducer orientation (at least one interval per hour for each transducer). The water column was broken into three equal depth intervals, that is, near bottom, middle and near surface thirds. The microcomputer programs created a summary file for each of the original six files. Each summary file contained a number of records equalling the number of time intervals at each location for each transducer. Each record contained the following data:
1) mid-interval time in minutes from start of study,
2) interval length in minutes,
3) number of targets which were digitized in each of the depth ranges,
4) numbers of targets per minute in each of the depth ranges,
5) weighted numbers in each of the depth intervals, and
6) weighted numbers per minute in each of the depth intervals.

Weighted numbers of fish were computed by letting each target equal the reciprocal of its range. This procedure provides a good approximation for the relative sample size of the various depth intervals since the vertical cross section of the acoustic beam in the water column increases linearly with range.

The commercial microcomputer applications program, Lotus 123 (Posner et al. 1983) was used to compute time of day, calculate current velocity data, and plot graphical representations of the summarized data. Another commercial microcomputer program, SPSS-PC+ (Norusis 1986) was used to compute Pearson's r and Kendall's Tau-c in order to investigate data associations.

## Slant Aspect Orientation

The change in range of a target passing through the slant angle transducer beam allowed determination of the direction of movement relative to the tidal current. However, the velocity of any individual target is impossible to measure with a single beam transducer because of the indeterminate path across the beam. For comparison purposes, the velocity of fish passage was approximated using a model in which the path of the fish is assumed to be horizontal in depth (Fig. 4).

## Fishing Effort

The species composition of the acoustic targets was investigated by gill net sampling. Three experimental and two commercial nets were used. Experimental net # 1 was a floating net 7.3m deep by 45.7m long with 6 cm mesh. Net # 2 was a floating net 1.7m deep by 17 m long with 4, 5, 6.5, 7.5 and 8.5 cm mesh. Net # 3 was a sinking net 1.5m wide by 21.3m long with 3.5 cm mesh. Nets # 4 and 5 were 600 m long commercial nets, fished top to bottom, one with 8.9 cm mesh and the other with 11.4 cm mesh. Both day and night samples were taken at Islas Cortezas. Only daytime sampling was completed at Isla Chira.

# RESULTS

## Islas Cortezas

The salinity and temperature data indicate a well mixed water column with little feature (Table 1). This probably resulted from the lack of rainfall during the dry season and the strong tidal and wind mixing. The tidal currents at the Islas Cortezas station appoached 1 m/sec (Fig. 5). A total of 2015 fish targets were detected at this station. The numbers of fish detected per hour of observation for the uplooking transducer are shown in Fig. 6a for the three portions of the water column. Corresponding values weighted by the inverse of range are given in Fig. 6b. The corresponding observations for the downlooking transducer are shown in Fig. 7. Both transducers detected more fish at night. This result is confirmed by the relation between detections and the night index (Fig. 8). The correlation between detection rates and the night index is strongest for the upper depth interval, but detection rates are significantly higher at night for the middle depth interval as well.

While there is an obvious diel effect on fish abundance at this station, the correlation between fish detections and tidal currents is weak (Fig. 9). The slant angle data indicate that most of the fish were moving with the current (Fig. 10). The correlation between detection rates and water speed is positive for all depths, but is signficant only in the middle depth interval.

A total of 77 fishes were caught at Islas Cortezas. They ranged in size from 6.5 to 57 cm, with a mean of 26.3 cm (Table 2). The catches were: Clupeidae (44.2%), Haemulidae (23.4%), Sciaenidae (14.3%), Ariidae (7.8%), Carangidae (5.2%) Engraulidae (3.9%) and Gerreidae (1.3%). Nets which fished the entire water column or the bottom caught sciaenids and ariids. Ariids were caught primarily at night while sciaenids were also caught during day. Clupeids, carangids and engraulids were caught day and night in nets which fished the surface or entire water column. Haemulids were caught in the middle water column.

Isla Chira

Salinities at the Isla Chira station were lower, as expected from the more estuarine location, but still show little structure (Table 1). Tidal currents also were less extreme with peak values about 0.7 m/sec (Fig. 11). A total of 2374 targets were detected. In contrast to Islas Cortezas, there are no significant correlations between the detection rates and the night index. However, a strong crepuscular component is present in the surface depth interval (Figs 12-14).

The slant angle data show that the fish again appeared to be moving at speeds and directions comparable with the tidal currents. However, the detection rates showed a weak inverse relationship with tidal current for the upper and middle water depths and for all targets combined (Fig. 15). The correlation approached significance for the middle depth interval ( alpha = 0.056).

Although the fishing effort at Isla Chira was less than half that at Islas Cortezas, the total catch was similar (Table 3). The catches were: Clupeidae (25.3%), Ariidae (21.1%), Engraulidae (19.7%), Haemulidae (11.3%), Sciaenidae (11.3%), Mugilidae (7.0%), Lutjanidae (2.8%) and Centropomidae (1.4%). Fish length ranged from 10.4 to 46 cm with a mean of 22 cm. Five small sharks and 4 penaeid shrimps were also caught. The distribution by depth was similar to that at Islas Cortezas except carangids were not found. Instead, mugilids were caught near bottom, while lutjanids were found from bottom to midwater.

## DISCUSSION

The objective of the stationary deployment was to achieve as complete water column coverage as possible so as to study the impact of fish behavior on the accessibility of fish to hydroacoustic techniques and possible clues to species identification. If the fish are fully available to the acoustic gear and moving passively with the current, the detection rate should be a direct function of the current velocity and abundance. The results indicate that most fish are moving at speeds comparable to the tidal current velocity. However, diel changes, rather than tidal, were the dominant component in the detections. Further, for the Chira location, the correlation between the number of detections and the speed of the tidal current was negative.

In the case of the Islas Cortezas station, the probable explanation is inshore movement at night. Hydroacoustic data from transecting in the area during day revealed the presence of large schools of fish in deep water just offshore of the station. Breakup and dispersion of these schools would account for the increased number of detections at night at this location.

The observed behavior at the Isla Chira station is more difficult to explain. No information is available on the horizontal distribution. Further, it is difficult to envision horizontal movements that would explain the crepuscular component. An alternate explanation is movement off bottom. This possibility is supported by the fact that the increased detection rate during the crepuscular periods was most evident in the upper water column. Even the stationary deployment is unable to detect fish in direct contact with the bottom. Further, upward migration at crepuscular periods for feeding purposes is common among fishes (Eggers 1978), and movement of pelagic organisms to the bottom during strong currents has been previously observed as an anti-washout mechanism in coastal upwelling areas (Blackburn and Thorne 1974).

If this interpretation is correct, it helps explain a characteristic of the commercial fishery. The gill nets for corvina are deployed in a drifting mode. A stationary deployment, perpendicular to currents, such as a set net, would involve greater risk to the nets in strong currents, but this risk would be easily offset by the greatly increased catch from the flux of fish movement if the fish were moving passively with the current. The results at Chira, where commercial catch rates generally much higher than at Cortesa, suggest that the fish may be more active during lower water velocity periods, and that activity obviously includes considerable movement relative to the tidal currents. Although the gill net catches during this study showed smaller than expected percentages of corvina, greater activity of these fish may provide a mechanism for selection of the larger and more commercially important fish.

The results confirm the capability of hydroacoustic gear to obtain considerable information on the behavior of fish. However, clearly both the fish behavior and species composition in this area is complex and further research is needed to develop effective direct assessment techniques. The equipment and procedures used in this study were relatively simple and inexpensive. This was justified both because of the preliminary nature of the study and the desire to develop cost effective procedures. However, more technologically complex research procedures may be necessary in order to develop the basis for future application of cost effective management procedures.

The initial results suggest that the transecting mode may be most efficient during lower water current periods. However, these data were very limited in horizontal coverage. Future studies need to include more transecting effort in order to better interpretate the significance of the stationary transducer observations. In addition, the complex species composition may require greater interaction with the fishery itself in order to better understand the spatial distribution of the corvina. Finally, this study was limited to the dry season. A greater impact of physical parameters on fish behavior, including that of tidal currents, is likely during the more estuarine conditions associated with the wet season.

## Literature Cited

Anon. 1985. SPSS:CDC Procedure no. 1 - Regression and nonlinear. Northwestern University Vogelback Computer Center.

Blackburn, M. and R.E. Thorne 1974. Composition and distribution of nekton in a coastal upwelling area off Baja California, Mexico. Tethys 6:281-290.

Eggers, D.M. 1978. Limnetic feeding behavior of juvenile sockeye salmon in Lake Washington and predator avoidance. Limnol.Ocean. 23(6):1114-1125.

Norusis, M.J. 1986. SPSS/PC+ for the IBM PC/XT/AT. SPSS Inc. Chicago, Il.

Nunnallee, E.P. 1980. Application of an empirically scaled digital echo integrator for assessment of juvenile sockeye salmon populations. Ph.D. thesis, Univ. Washington, Seattle. 151p.

Posner, J., J. Hill, S.E] Miller, E. Gottheil and M.C. Davis. 1983. Lotus 123 User's Manual.

Lotus Development Corporation. Cambridge, MA 361

Thorne, R.E. 1979. The application of hydroacoustics to tropical small-scale fishery stock assessment. Pages 110-118 in P. Roedel and S. Saila, eds, Proc. Workshop on Tropical Small-Scale Fishery Stock Assessment. International Center for Marine Resource Development, Univ. Rhode Island.

Thorne, R.E. 1980. Application of stationary hydroacoustic systems for studies of fish abundance and behavior. Pages 381-385 in Proc. Oceans 80.

Thorne, R.E. 1983a. Assessment of population abundance by echo integration. Biol. Ocean. J. 2:253-262.

Thorne, R.E. 1983b. Hydroacoustics. Chapt. 12 in L. Nielson and D. Johnson (eds) Fisheries Techniques. American Fisheries Society, Bethesda, Md.

Table 1. Bottom and surface salinity and temperature at Islas Cortezas and Isla Chira, 17, 18 and 19 February 1987.

| Date | Station | Time | Salinity (ppt) Surface | Salinity (ppt) Bottom | Temperature ( C) Surface | Temperature ( C) Bottom |
|---|---|---|---|---|---|---|
| 17 Feb | Cortezas | 1200 | 32.0 | 31.5 | 28 | 28 |
| | | 1300 | 32.0 | 31.7 | 29 | 28 |
| | | 1400 | 32.5 | 32.7 | 28 | 27.5 |
| | | 1515 | 32.3 | 32.0 | 28.7 | 28 |
| | | 1630 | 31.2 | 31.2 | 28.0 | 28.0 |
| | | 1710 | 31.5 | 31.5 | 28 | 27.5 |
| | | 1808 | 30.0 | 29.3 | 28 | 28 |
| | | 1900 | 30.5 | 30.5 | 28 | 28 |
| | | 2000 | 30.7 | 30.8 | 28 | 28 |
| | | 2100 | 30.5 | 30.2 | 28 | 28 |
| | | 2210 | 29.2 | 29.1 | 27.5 | 27.7 |
| | | 2300 | 28.0 | 27.5 | 27.5 | 27.5 |
| | | 2400 | 27.5 | 27.0 | 27.5 | 27.5 |
| 18 Feb | | 0058 | 29.7 | 29.5 | 28 | 28 |
| | | 0157 | 30.2 | 30.1 | 27 | 27.5 |
| | | 0308 | 29.8 | 29.8 | 27.1 | 27.1 |
| | | 0358 | 30 | 30 | 27 | 27.2 |
| | | 0459 | 30 | 30 | 27.1 | 27.1 |
| | | 0600 | 30 | 30 | 27 | 27.1 |
| | | 0700 | 29.6 | 29.8 | 27.2 | 27.2 |
| | | 0800 | 29.3 | 29.2 | 28.1 | 27.6 |
| | | 0904 | 29.7 | 29.7 | 27.8 | 27.9 |
| | | 1000 | 29.3 | 29.2 | 28.0 | 28.0 |
| | | 1100 | 28.9 | 28.9 | 28.8 | 28.1 |
| 18 Feb | Chira | 1800 | 28.0 | 27.0 | 30.3 | 30.1 |
| | | 1900 | 27.8 | 26.9 | 30.2 | 30.0 |
| | | 1956 | 28 | 28 | 32 | 30 |
| | | 2100 | 27 | 26.3 | 30 | 30 |
| | | 2157 | 27 | 27 | 30 | 30 |
| | | 2254 | 27 | 25 | 29.5 | 30 |
| | | 2358 | 26.5 | 26.2 | 29.3 | 29.8 |
| 19 Feb | | 0100 | 26.1 | 25 | 29 | 29.1 |
| | | 0156 | 25.5 | 25.7 | 29.5 | 29.6 |
| | | 0300 | 26 | 25 | 29 | 29.5 |
| | | 0401 | 26.2 | 25.6 | 29.5 | 29.9 |
| | | 0501 | 26.6 | 26.1 | 29.3 | 29.8 |
| | | 0601 | 26.2 | 25.3 | 29.2 | 29.7 |
| | | 0701 | 26.6 | 26.9 | 29.2 | 29.5 |
| | | 0800 | 26.8 | 25.2 | 29.1 | 29.2 |
| | | 0902 | 26.3 | 26.7 | 29.5 | 29.9 |
| | | 1001 | 24.8 | 24.9 | 30.8 | 30.1 |
| | | 1100 | 24.8 | 24.6 | 30.4 | 30.1 |
| | | 1200 | 24.8 | 24.8 | 30.1 | 29.9 |
| | | 1300 | 24.1 | 24.9 | 30.2 | 29.9 |
| | | 1401 | 25 | 24 | 30.8 | 30.2 |
| | | 1503 | 25 | 24.7 | 30.4 | 30.2 |
| | | 1600 | 24.8 | 24.9 | 31 | 30 |

Table 2. Fishes caught by gillnets at Islas Cortezas, 17 and 18 February 1987.

| Species | Local Name | Family | Number | Length (cm) Mean | S.D. |
|---|---|---|---|---|---|
| (17 Feb 1245-1445 Net 1) | | | | | |
| Oligoplites sp. | Sierra | Carangidae | 1 | 25.0 | |
| Caranx vinctus | Jurel | Carangidae | 1 | 27.5 | |
| Ilisha furthii | Plastica | Clupeidae | 4 | 27.9 | 1.3 |
| Ophistonema libertate | Gallera | Clupeidae | 17 | 25.2 | 1.4 |
| Anchoa sp. | Anchoa | Engraulidae | 1 | 21.5 | |
| Pomadasys sp. | Roncadores | Haemulidae | 1 | 20.5 | |
| (17 Feb 1245-1445 Net 2) | | | | | |
| Lille stolifera | Sardina | Clupeidae | 1 | 15.3 | |
| (17 Feb 1245-1445 Net 3) | | | | | |
| Cynoscion phoxocephalus | Picuda | Sciaenidae | 1 | 17.5 | |
| (17 Feb 1500-1700 No Catch in Nets 1, 2, 3) | | | | | |
| (17 Feb 1800-2300 Net 4) | | | | | |
| Pomadasys sp. | Roncadores | Haemulidae | 4 | 27.7 | 3.6 |
| Cynoscion squamipinnis | Aguada | Sciaenidae | 3 | 45.6 | 4.5 |
| Ophioscion sp. | China | Sciaenidae | 1 | 24.5 | |
| (17 Feb 1800-2300 Net 5) | | | | | |
| Arius sp. | Cuminate | Ariidae | 1 | 57.0 | |
| Anisostremus sp. | Coton | Haemulidae | 1 | 32.8 | |
| (17,18 Feb 1700-0800 Net 1) | | | | | |
| Arius sp. | Cuminate | Ariidae | 4 | 25.8 | 5.3 |
| Ilisha furthii | Plastica | Clupeidae | 3 | 26.1 | 1.3 |
| Anchoa sp. | Anchoa | Engraulidae | 1 | 18.0 | |
| (17,18 Feb 1700-0800 Net 2) | | | | | |
| Ilisha furthii | Plastica | Clupeidae | 9 | 15.0 | 0.9 |
| Anchoa sp. | Anchoa | Engraulidae | 1 | 17.6 | |
| (17,18 Feb 1700-0800 Net 3: net severely damaged on retreival) | | | | | |
| Arius sp. | Cuminate | Ariidae | 1 | 22.5 | |
| (18 Feb 0005-1000 Net 4) | | | | | |
| Haemulon panamensis | Roncador | Haemulidae | 1 | 32.0 | |
| Cynoscion squamipinnis | Aguada | Sciaenidae | 3 | 43.7 | 4.2 |
| (18 Feb 0005-1000 Net 5) | | | | | |
| Caranx vinctus | Jurel | Carangidae | 1 | 43.0 | |
| Selene sp. | Palometa | Carangidae | 1 | 19.5 | |
| Diapterus peruvianus | Palmitos | Gerridae | 1 | 23.5 | |
| Haemulon panamensis | Roncador | Haemulidae | 3 | 33.2 | 1.2 |
| Anisotremus dovii | Viejas | Haemulidae | 9 | 28.5 | 1.3 |
| Ophioscion sp. | China | Sciaenidae | 1 | 26.5 | |
| (18 Feb 0800-1330 Net 1) | | | | | |
| Ophioscion imiceps | Corvina china | Sciaenidae | 1 | 12.5 | |
| | Corvina | Sciaenidae | 1 | 6.5 | |

Table 3. Fishes caught by gillnets at Isla Chira, 19 February 1987.

| Species | Local Name | Family | Number | Length (cm) Mean | S.D. |
|---|---|---|---|---|---|
| (19 Feb | 0800-1500 | Net 4) | | | |
| Arius sp. | Cuminate | Ariidae | 1 | 37.8 | |
| Pomadasys sp. | | Haemulidae | 4 | 26.0 | 0.7 |
| (19 Feb | 0800-1500 | Net 5) | | | |
| Arius sp. | Cuminate | Ariidae | 1 | 46.0 | |
| Anisotremus dovii | Viejas | Haemulidae | 3 | 30.7 | 1.7 |
| Pomadasys leuciscus | | Haemulidae | 1 | 37.0 | |
| (19 Feb | 0900-1030 | Net 1) | | | |
| Arius sp. | Cuminate | Ariidae | 4 | 25.0 | 1.5 |
| Caranx vinctus | Jurel | Carangidae | 1 | 25.0 | |
| Ophistonema libertate | Gallera | Clupeidae | 3 | 26.1 | 2.5 |
| Lutjanus guttatus | Pargo de la mancha | Lutjanidae | 1 | 22.0 | |
| L. argentiventris | Pargo coliamarilla | Lutjanidae | 1 | 28.5 | |
| (19 Feb | 1045-1125 | Net 1) | | | |
| Carcharhinus longurie | | Carcharhinidae | 2 | 32.5 | 6.4 |
| Ophistonema libertate | Gallera | Clupeidae | 2 | 22.0 | 4.2 |
| Ophioscion sp. | China | Sciaenidae | 2 | 18.1 | 2.7 |
| Penaeus stylirostris | Camaron | Penaeidae | 1 | 12.0 | |
| (19 Feb | 1130-1300 | Net 1) | | | |
| Arius sp. | Cuminate | Ariidae | 5 | 19.3 | 4.6 |
| Carcharhinus longurie | | Carcharhinidae | 1 | 33.5 | |
| Lille stolifera | Sardina | Clupeidae | 1 | 14.5 | |
| Ophistonema libertate | Gallera | Clupeidae | 1 | 29.8 | |
| Anchoa sp. | Anchoa | Engraulidae | 2 | 20.2 | 0.1 |
| Bardiella armata | | Sciaenidae | 1 | 21.7 | |
| (19 Feb | 1130-1300 | Net 2) | | | |
| Penaeus stylirostris | Camaron | Penaeidae | 1 | 15.0 | |
| (19 Feb | 1310-1450 | Net 1) | | | |
| Arius sp. | Cuminate | Ariidae | 4 | 16.2 | 1.5 |
| Centropomus unioneuses | Robalo | Centropomidae | 1 | 16.1 | |
| Lille stolifera | Sardina | Clupeidae | 10 | 14.8 | 0.6 |
| Ophistonema libertate | Gallera | Clupeidae | 1 | 16.2 | |
| Anchoa sp. | Anchoa | Engraulidae | 12 | 20.1 | 0.9 |
| Mugil curema | Lisa | Mugilidae | 5 | 26.7 | 5.8 |
| Nebris occidentalis | | Sciaenidae | 1 | 18.7 | |
| Cynoscion albus | Reina | Sciaenidae | 1 | 18.8 | |
| Stellifer sp. | | Sciaenidae | 3 | 11.4 | 1.7 |
| Penaeus stylirostris | Camaron | Penaeidae | 1 | 16.7 | |
| Trachipenaeus sp. | Camaron | Penaeidae | 1 | 12.9 | |
| (19 Feb | 1310-1450 | Net 2) | | | |
| Carcharhinus longurie | | Carcharhinidae | 2 | 26.4 | |

# List of Figures

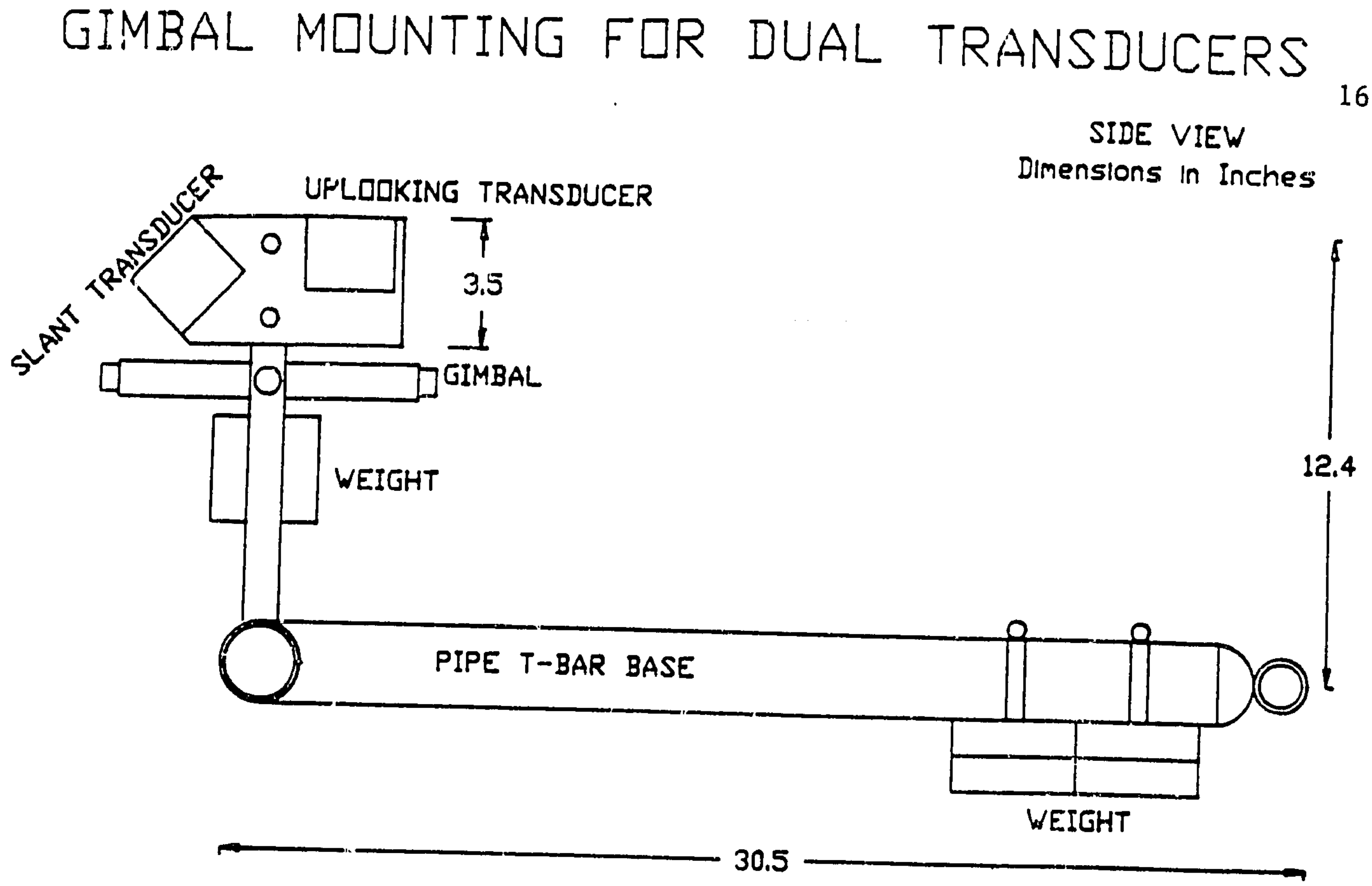



Fig. 2. Schematic of gimbal mount used for transducer deployment on bottom.

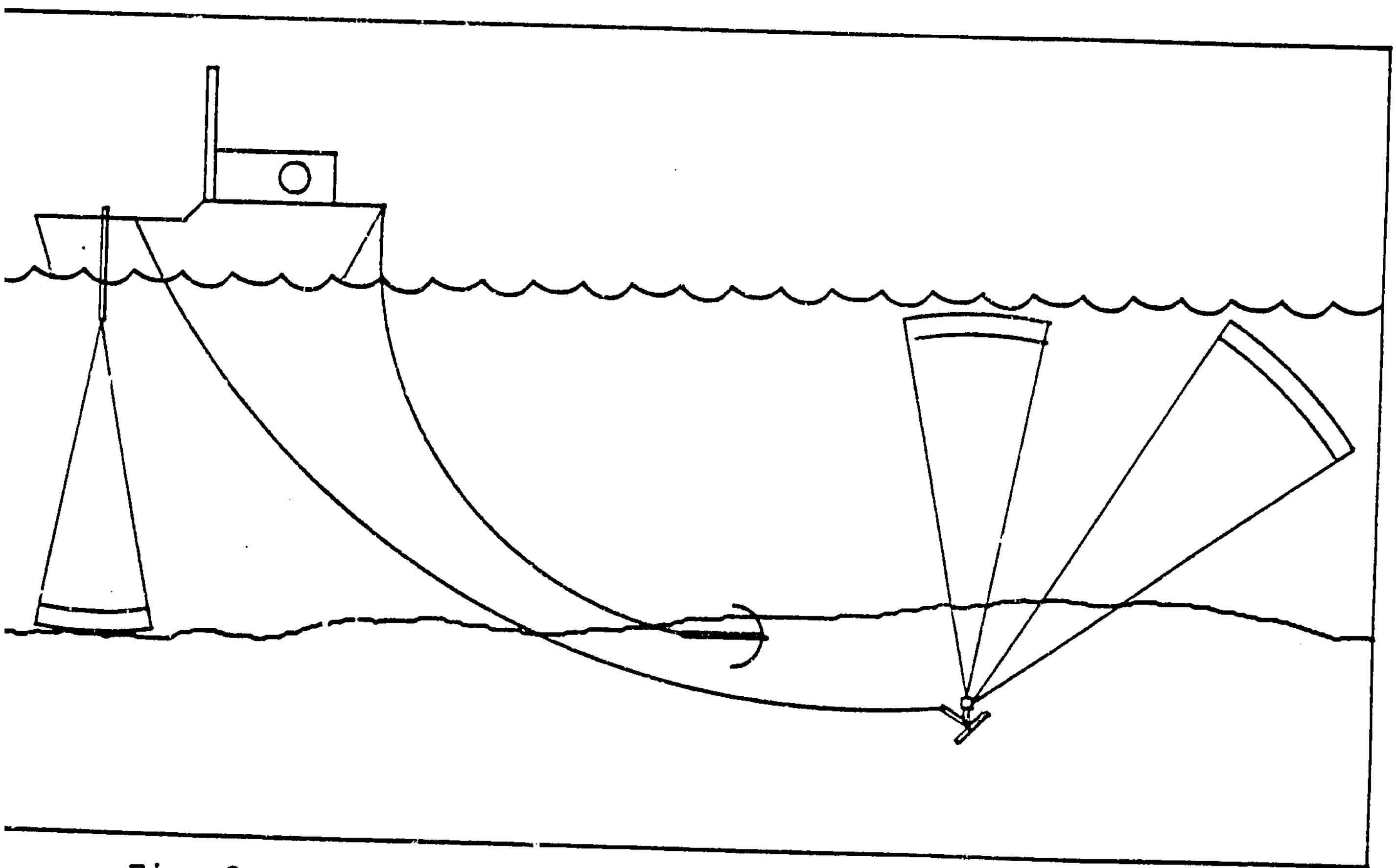
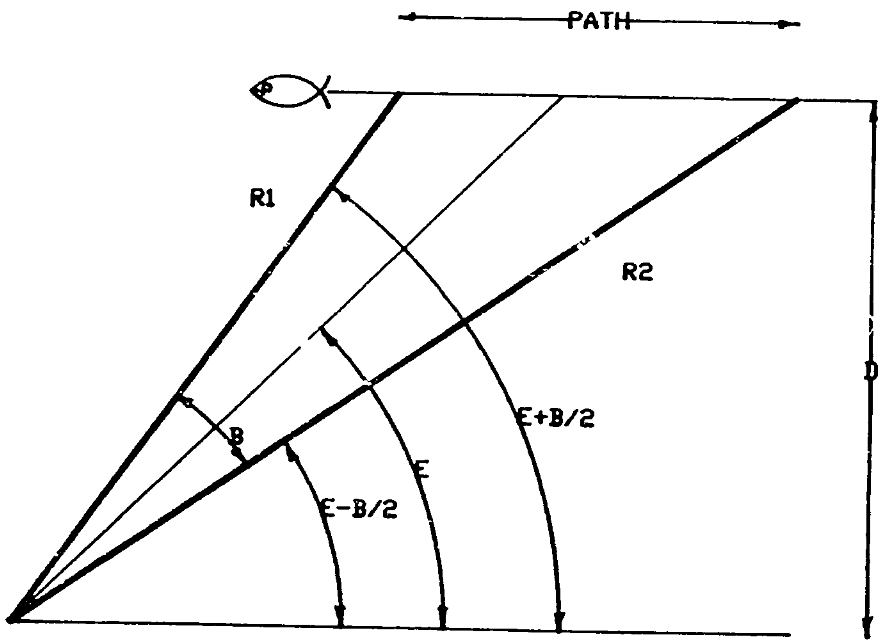


Fig. 3. Schematic of three transducer deployment at anchor station.

# HORIZONTAL MODEL FOR PATH LENGTH APPROXIMATION




$$\tan \frac{B}{2} = \frac{R2-R1}{R1+R2} \times \tan E$$

$$PATH^2 = R1^2 + R2^2 - 2\ R1\ R2 \cos B$$

E = TRANSDUCER ANGLE
B = EFFECTIVE BEAM ANGLE
R1 = CLOSEST RANGE
R2 = FARTHEST RANGE

Fig. 4. Horizontal model for path length approximation.

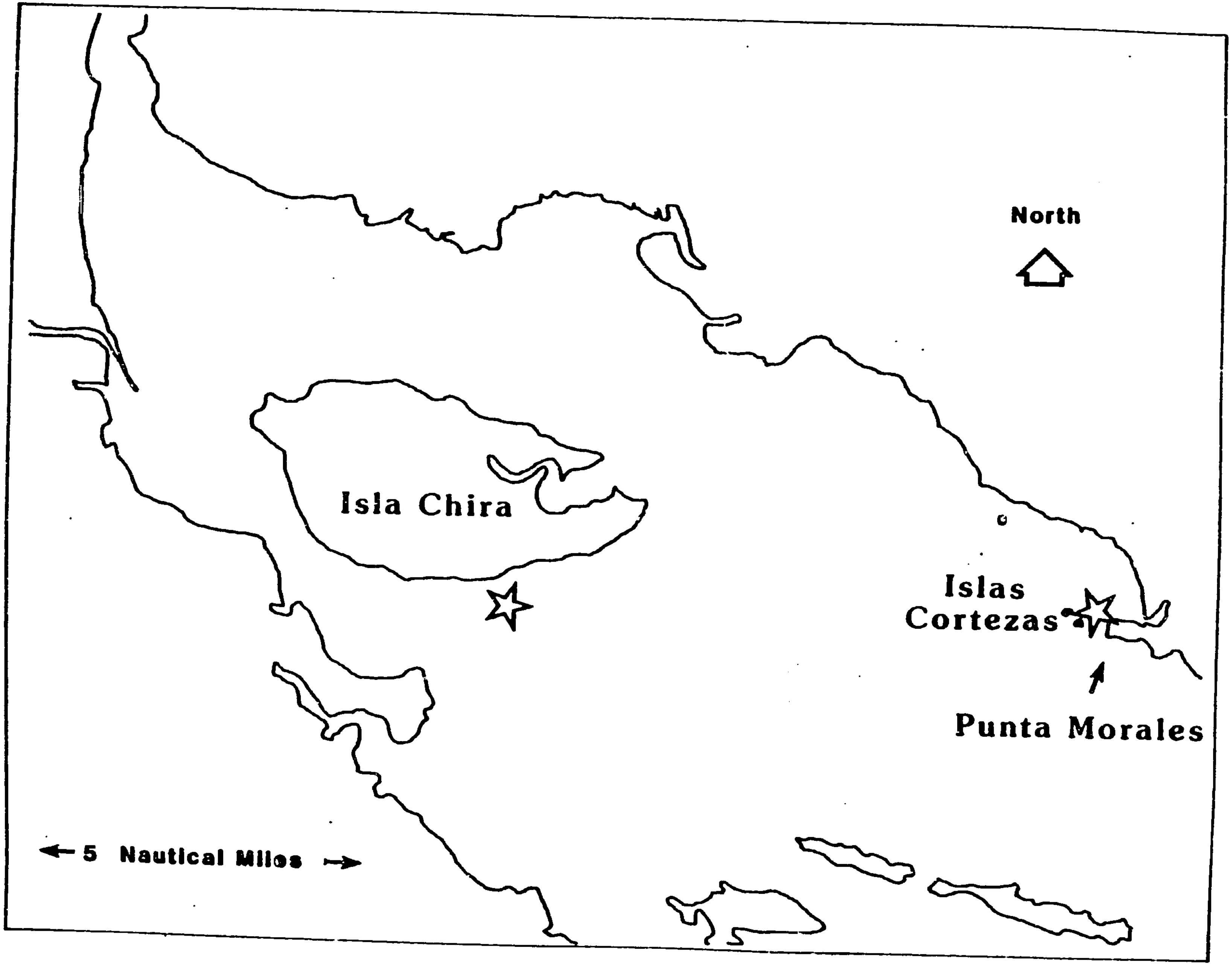



Fig. 1. Location of anchor stations in the Gulf of Nicoya.

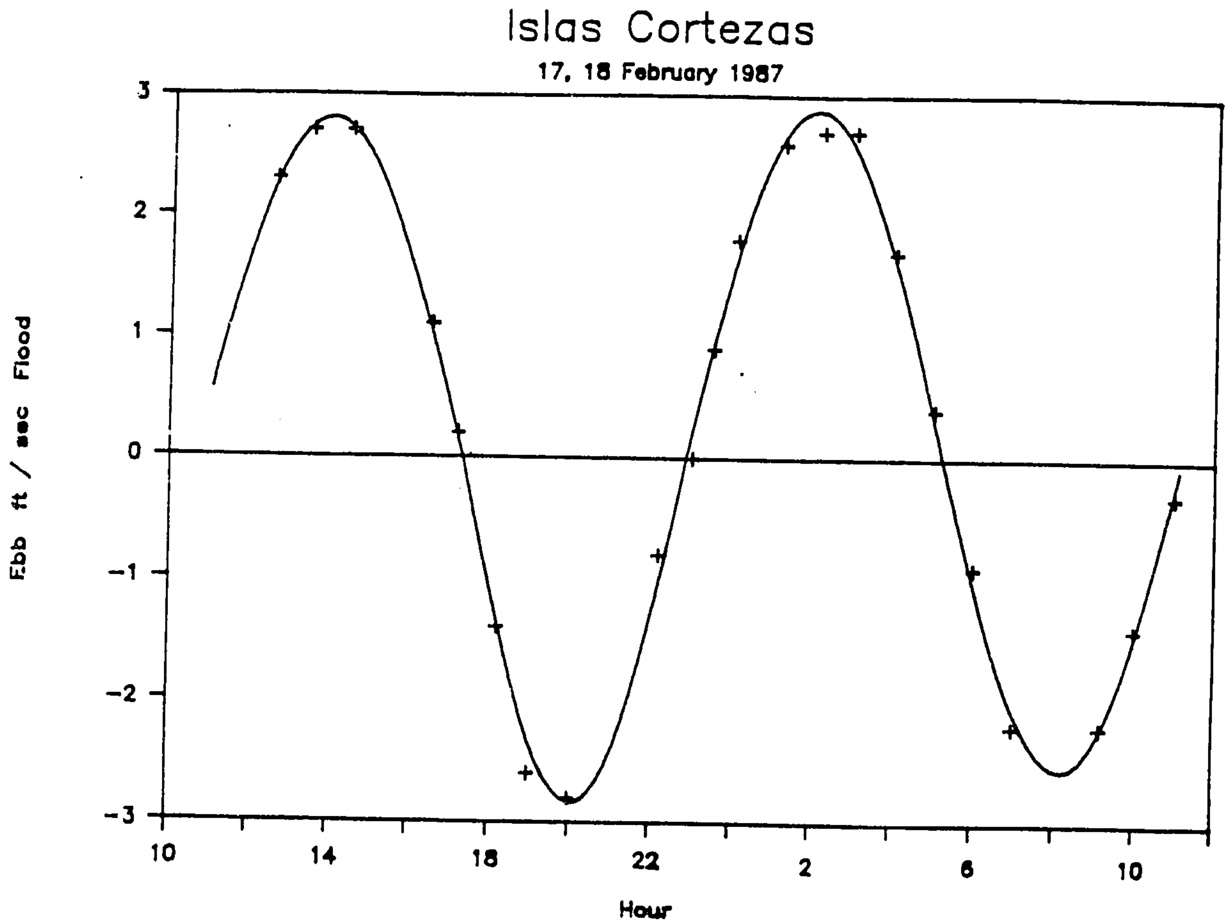
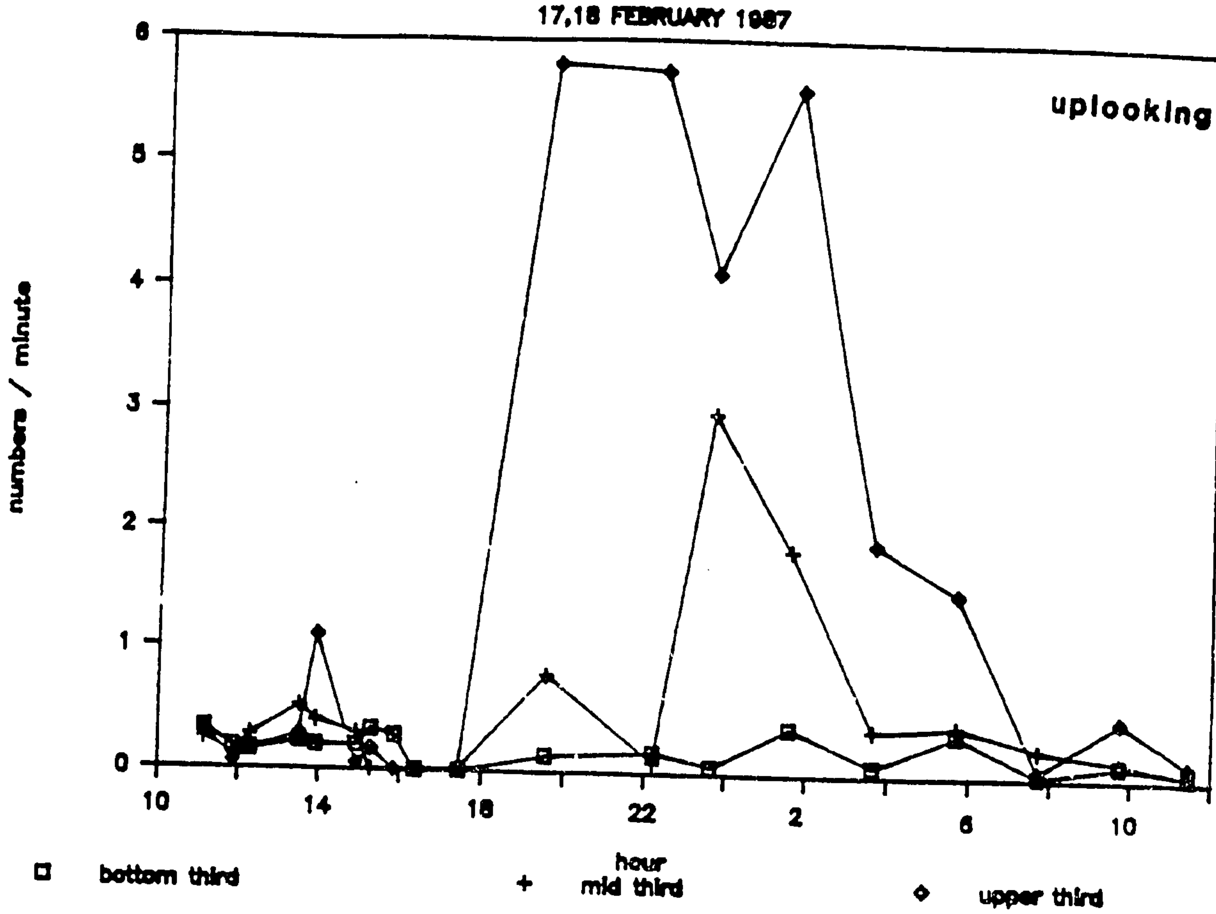



Fig. 5.. Tidal currents at the Islas Cortesa anchor station.



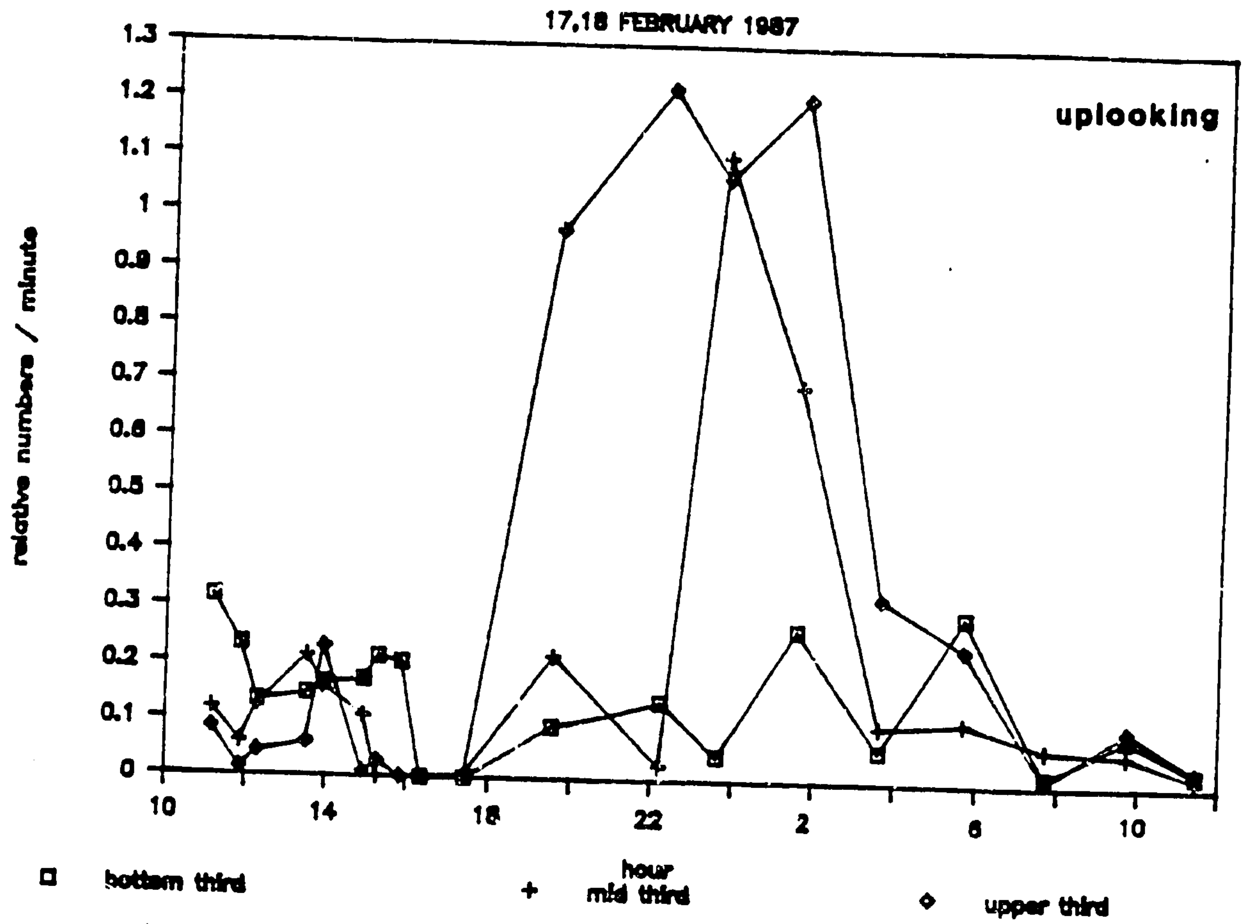
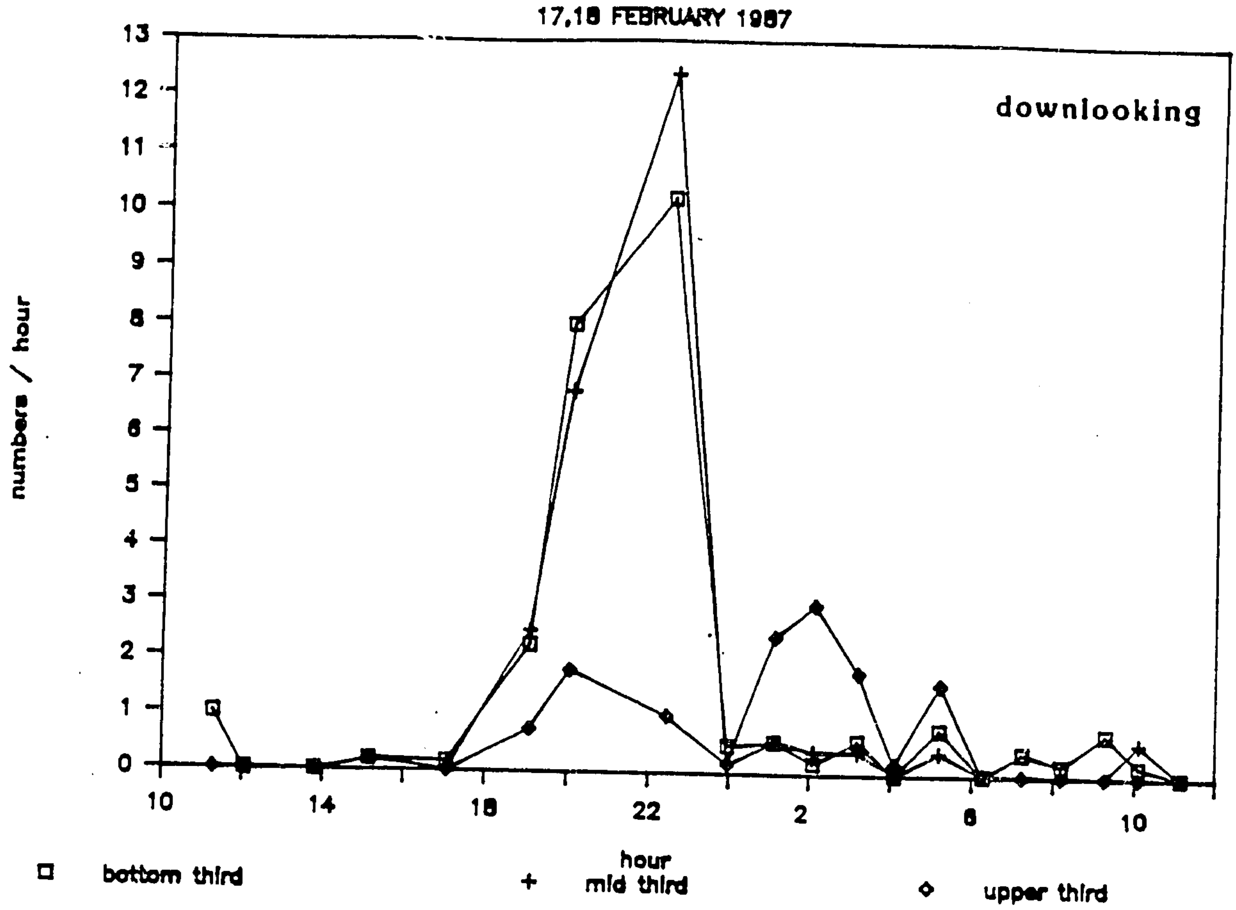




Fig. 6. Actual and weighted fish detection rates from the uplooking transducer at the Islas Cortezas station.



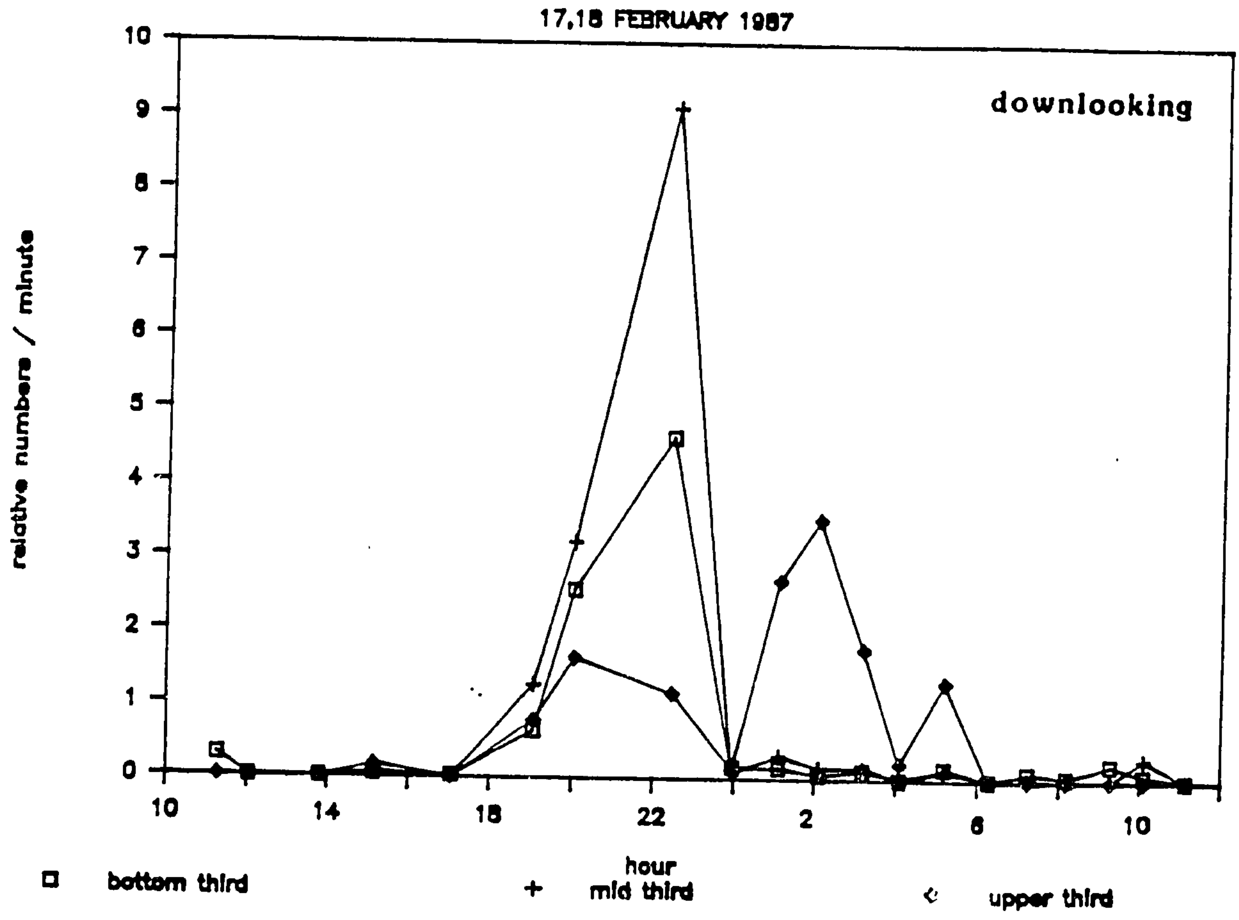




Fig. 7. Actual and weighted detection rates from the downlooking transducer at the Islas Cortezas station.

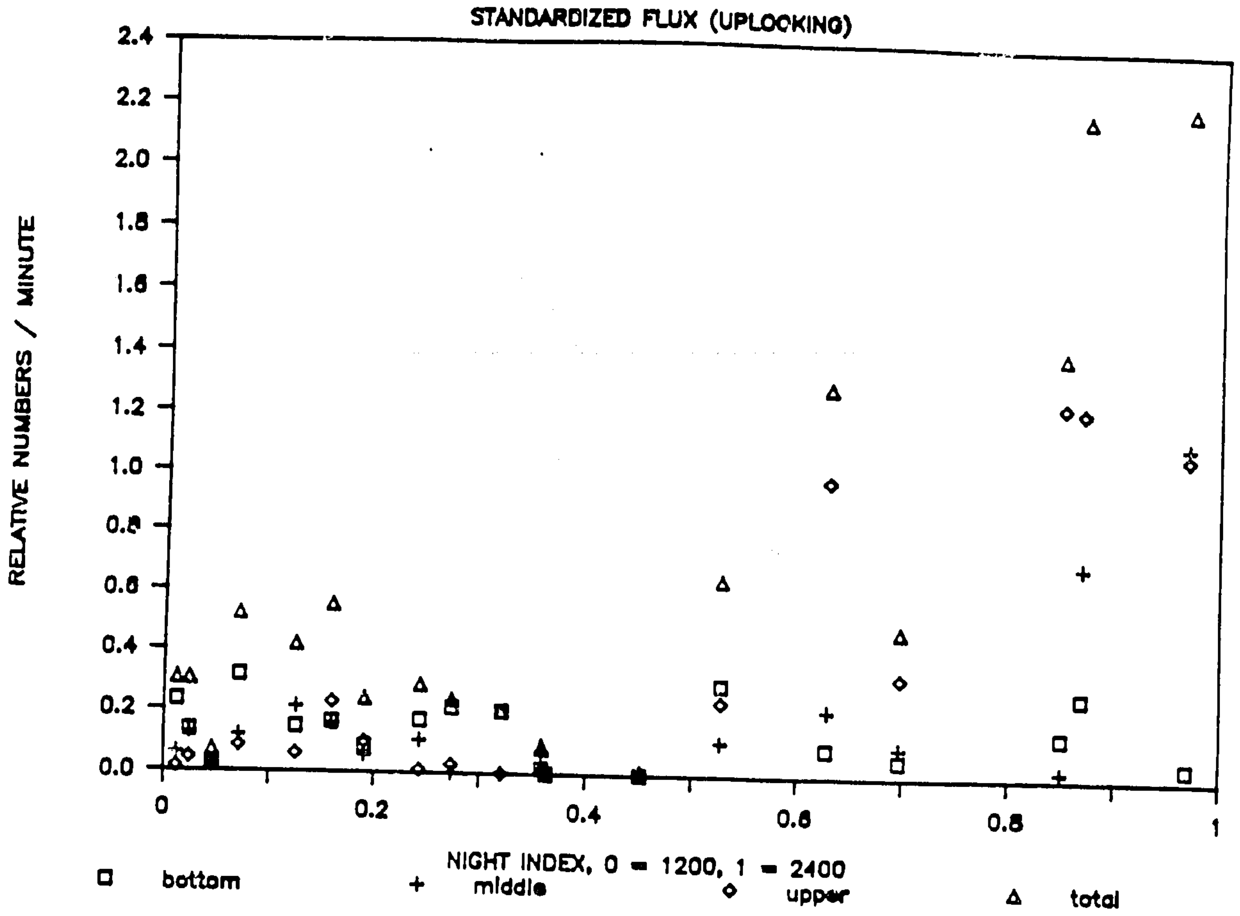



Fig. 8. Relation between detections and night index for the uplooking transducer, Islas Cortezas.

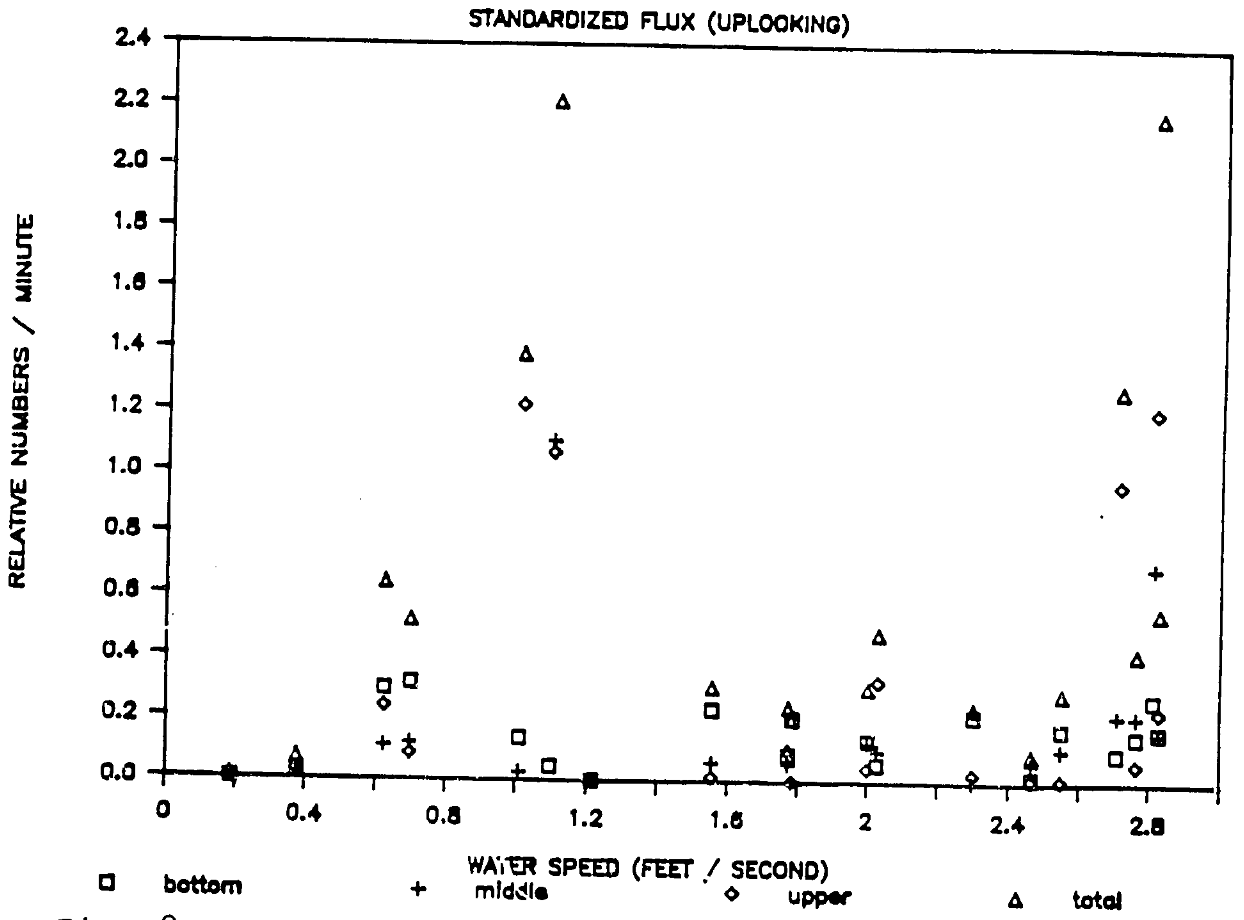



Fig. 9. Relation between fish detections and water current speed, Islas Cortezas.

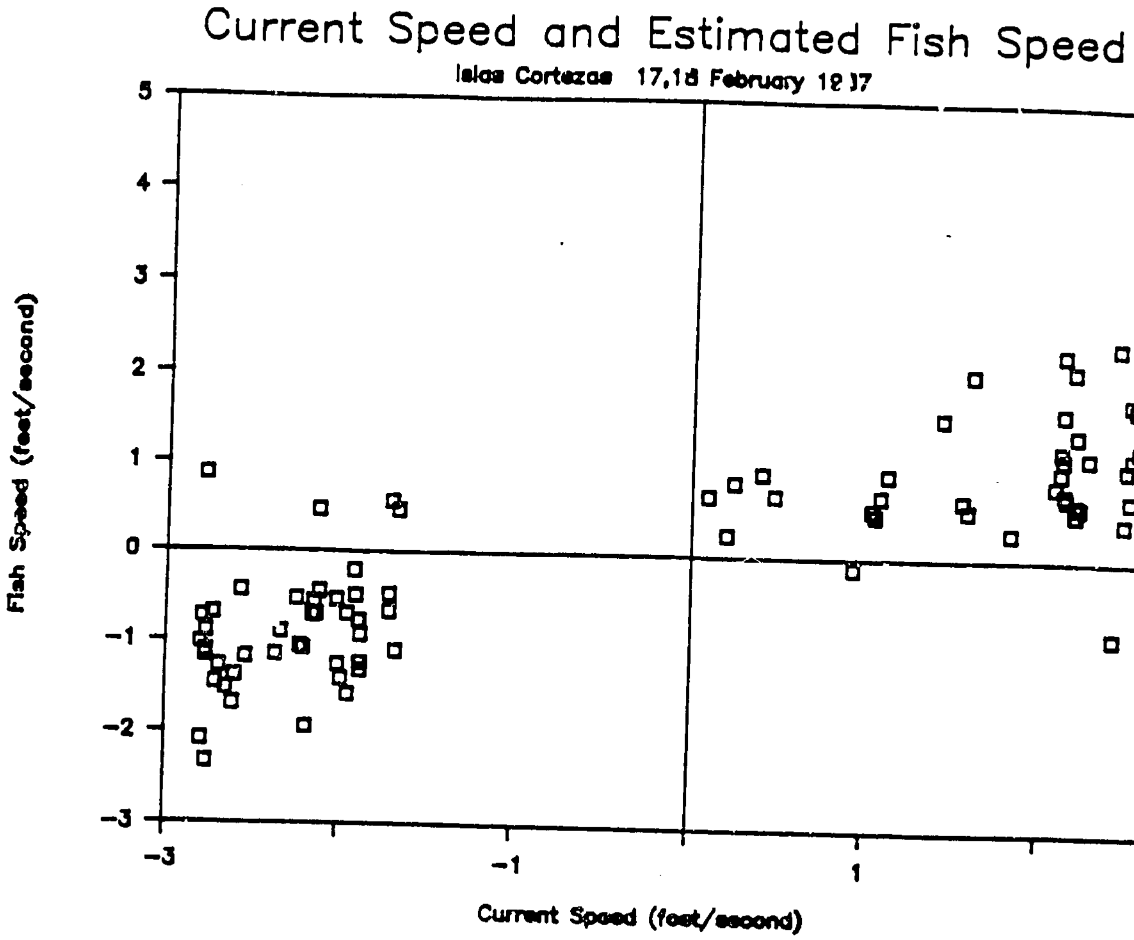



Fig. 10. Relation between water current speed and estimated speed of fish, Islas Cortezas.

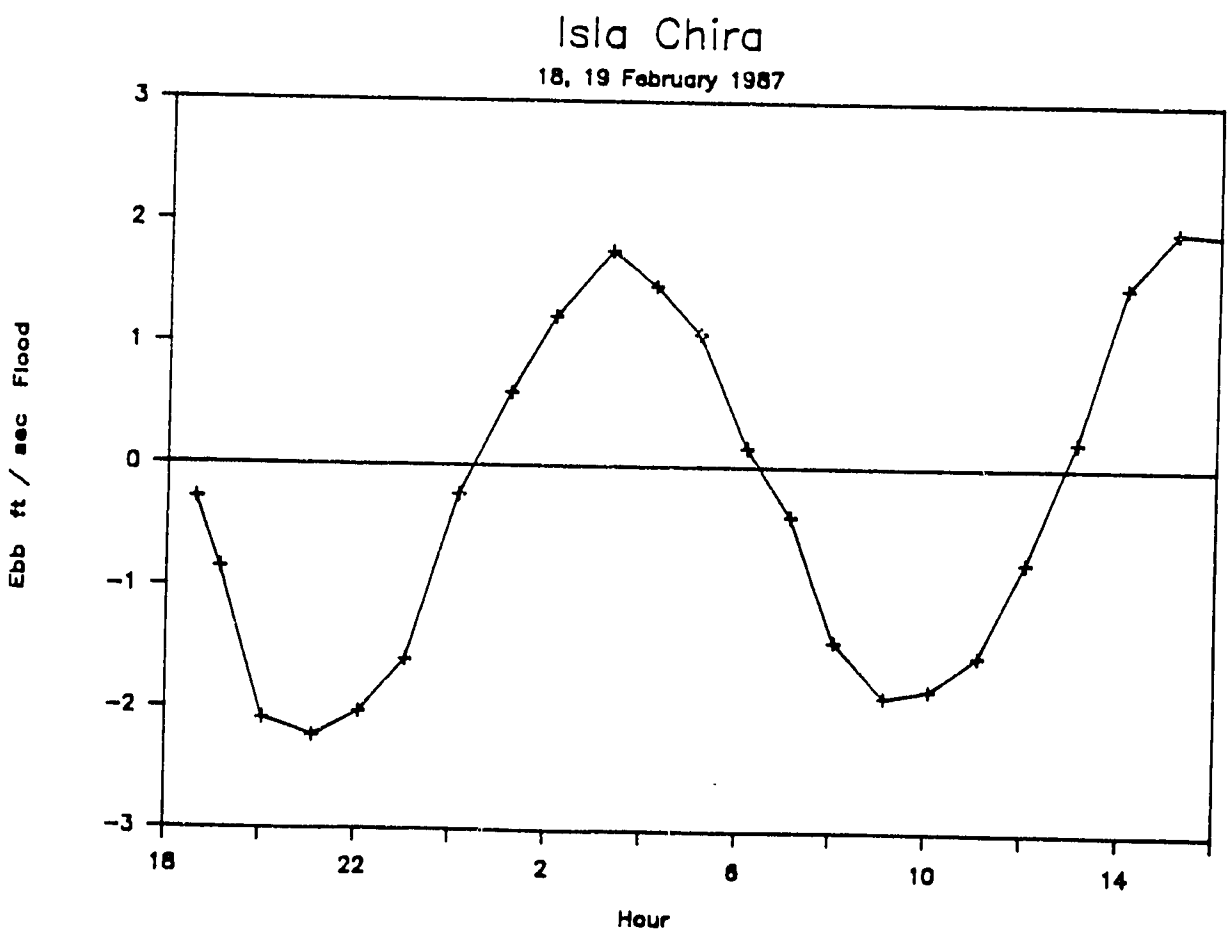
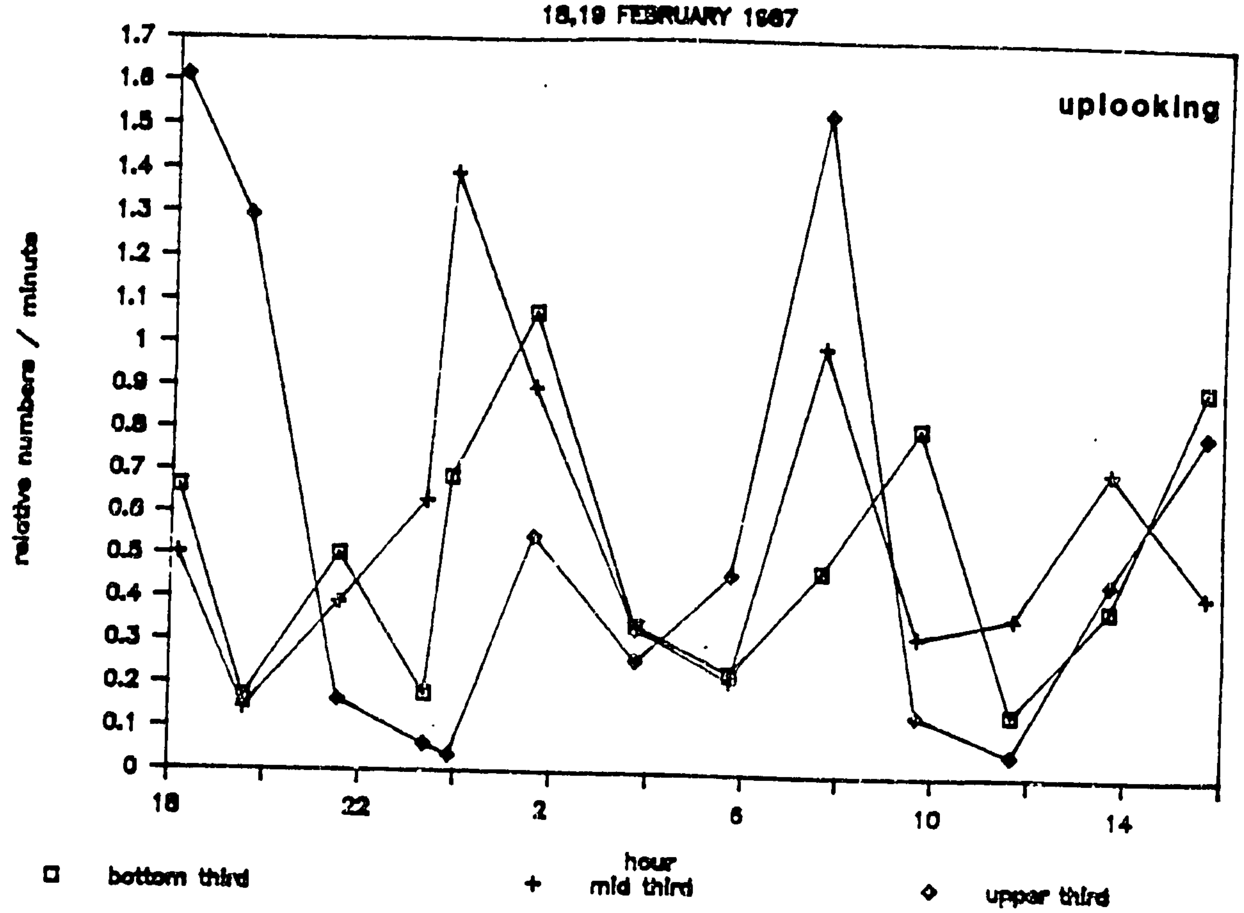



Fig. 11. Tidal currents at the Isla Chira station.



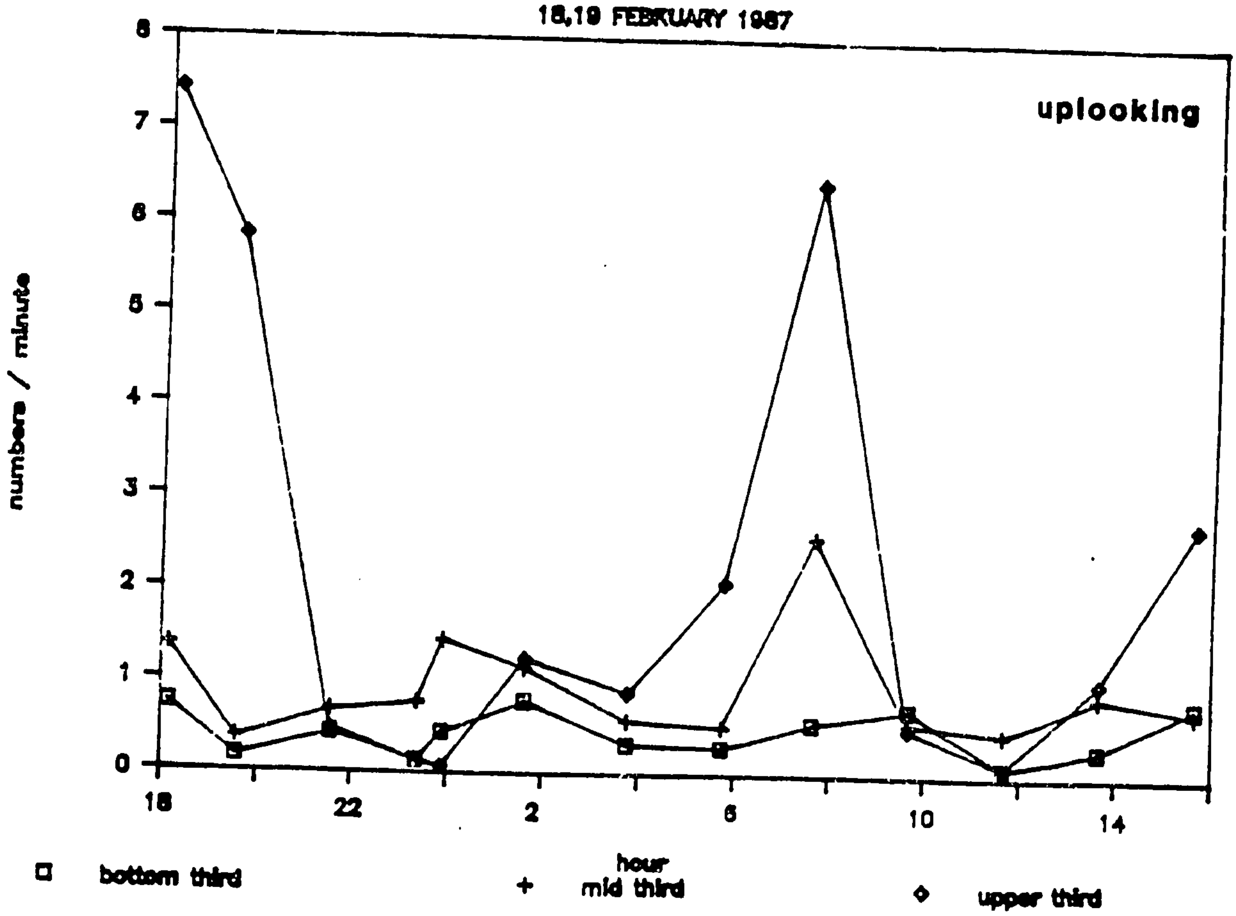
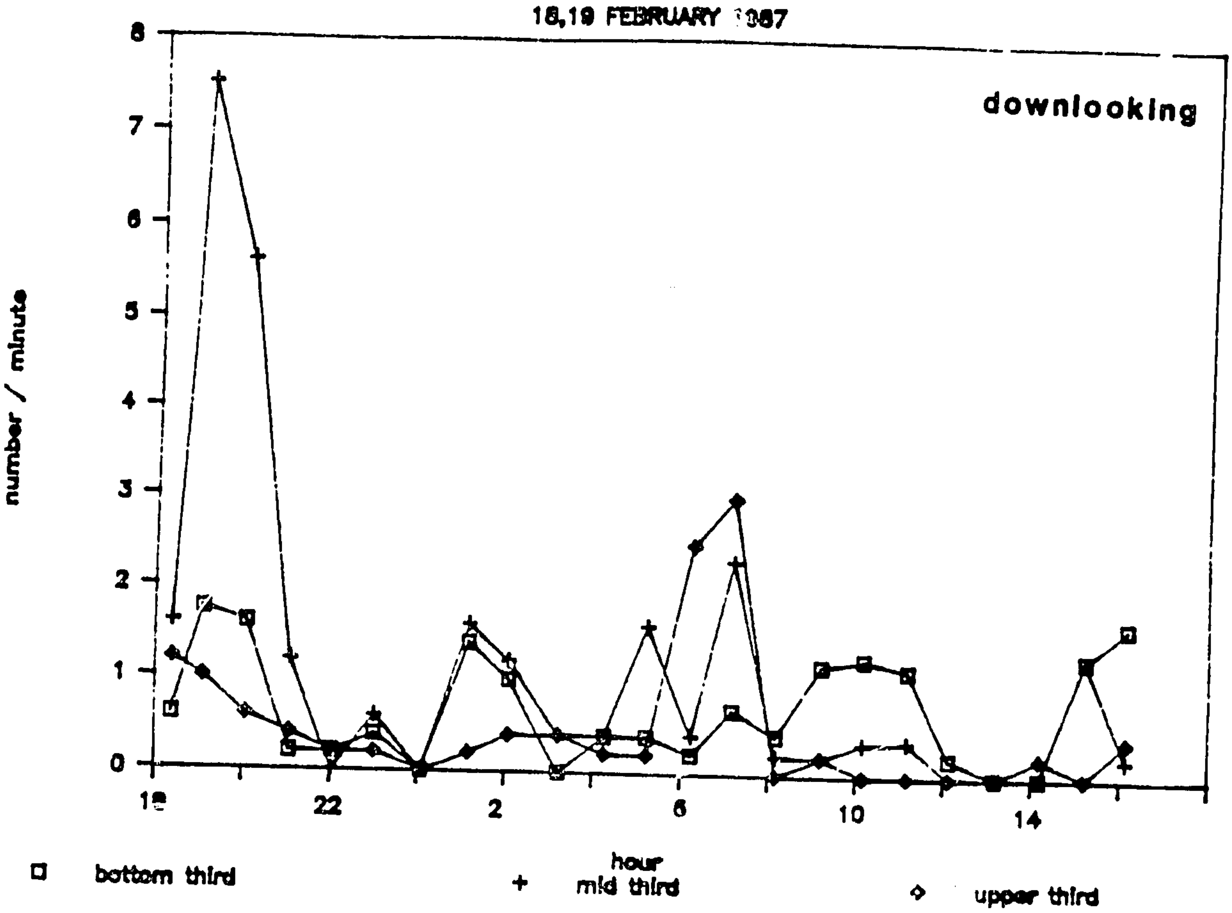




Fig. 12. Actual and weighted detection rates for uplooking transducer, Isla Chira.



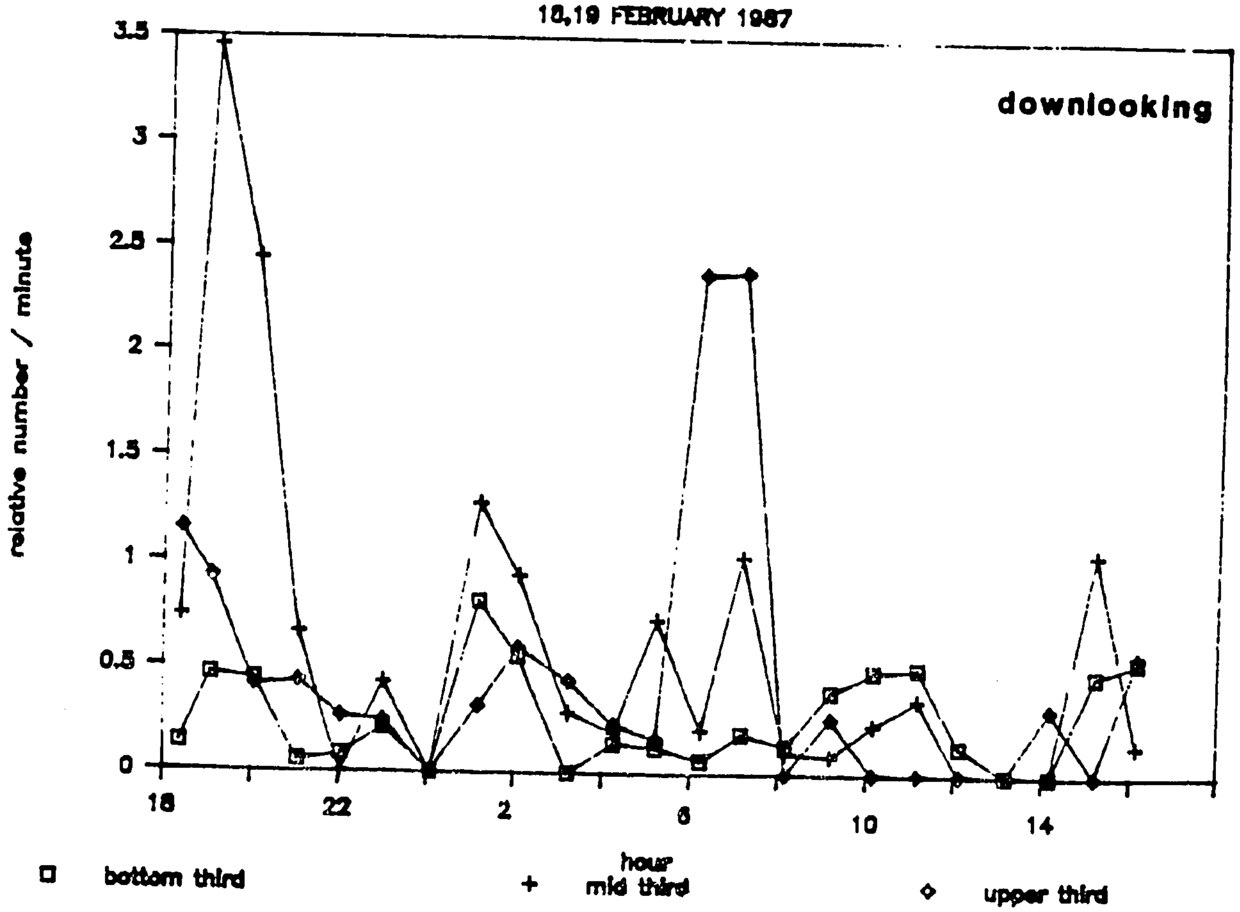




Fig. 13. Actual and weighted detection rates for downlooking transducer, Isla Chira.

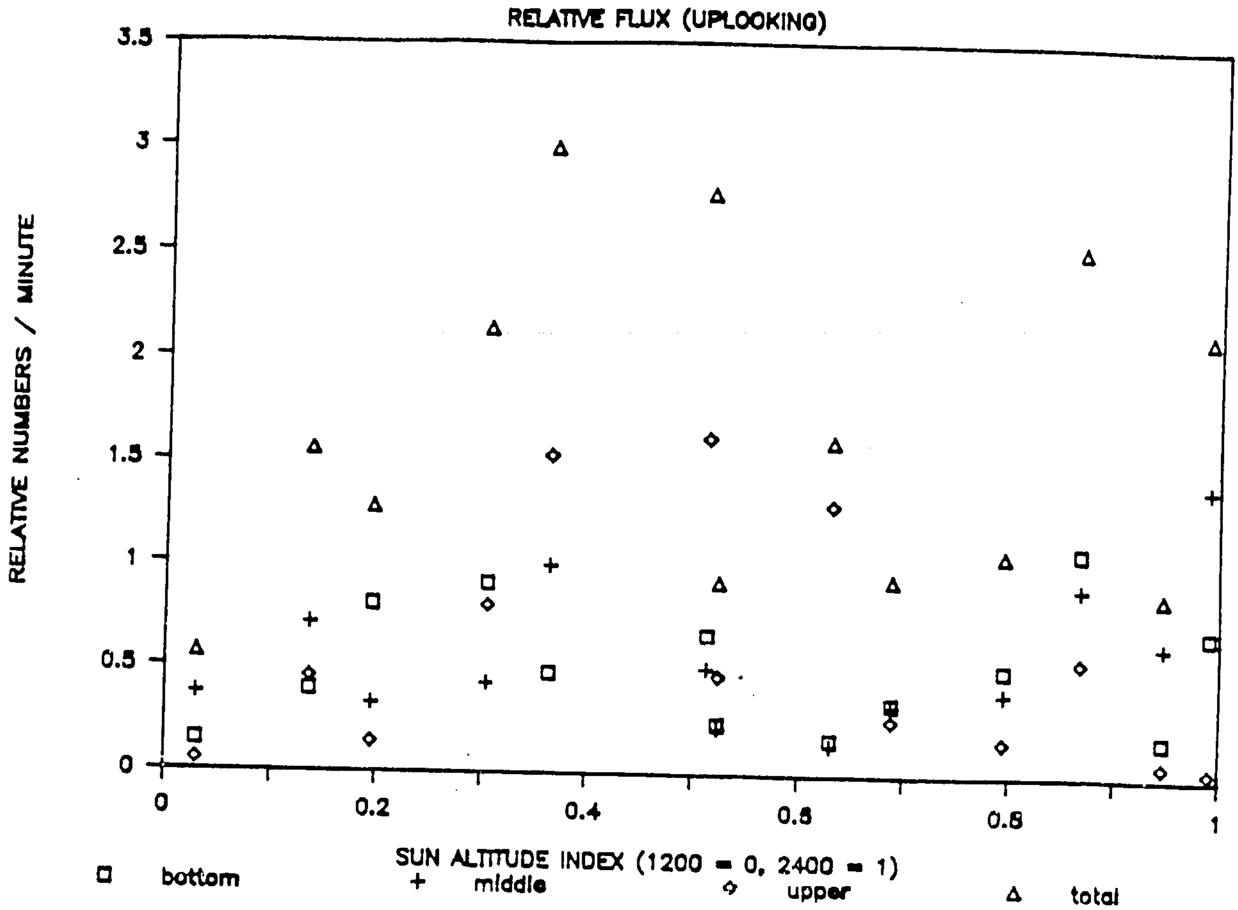



Fig. 14. Relation between detections and night index, Isla Chira.

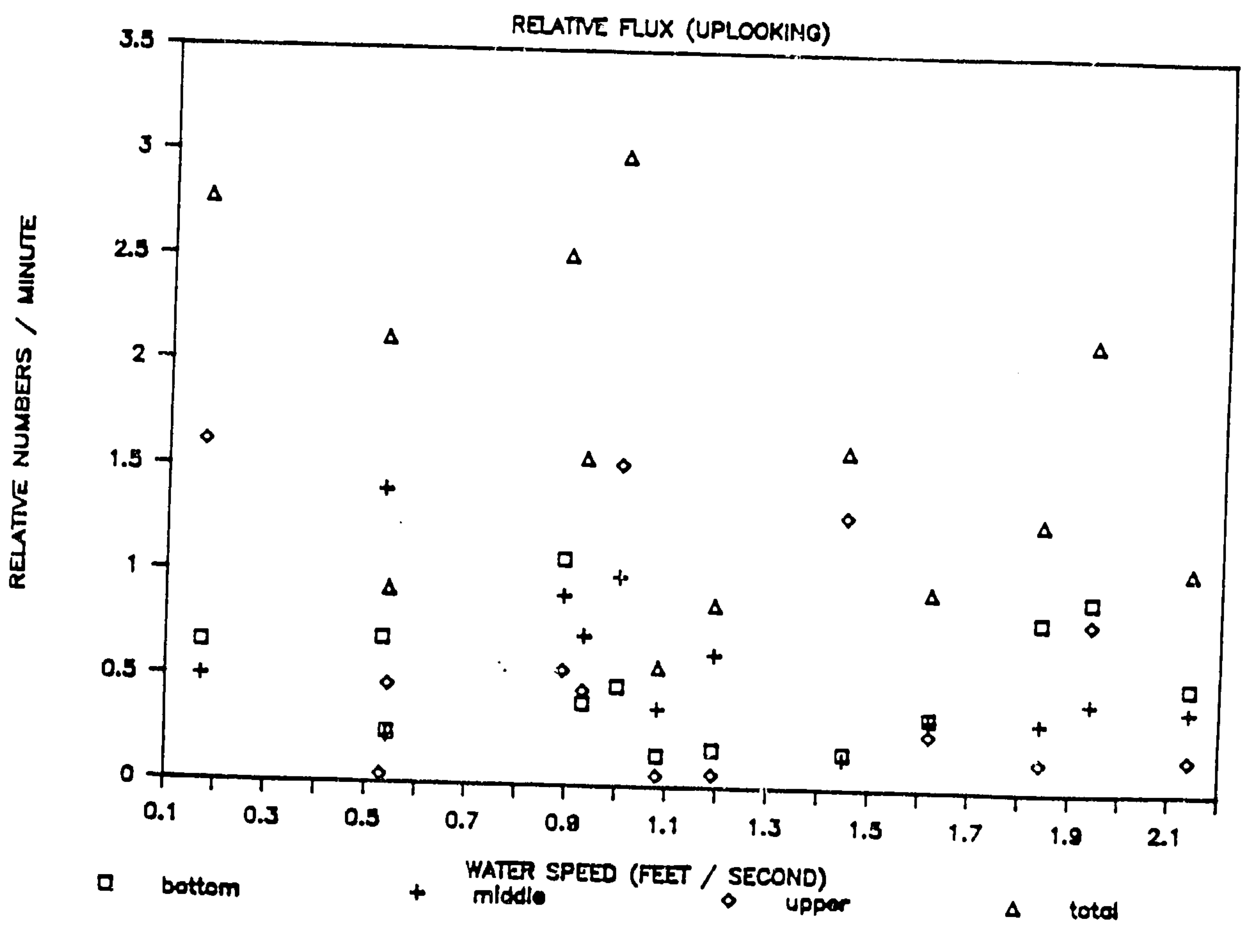



Fig. 15. Relation between detections and water current speed, Isla Chira.