The harvest per unit effort (cpue) of *Gelidium robustum* along Baja California Peninsula and its relationship with temperature and upwelling

MARGARITA CASAS-VALDEZ[1,4,5], ELISA SERVIERE-ZARAGOZA[2], SOFÍA ORTEGA-GARCÍA[1,4], DAVID LORA-SÁNCHEZ[3] and CLAUDIA J. HERNÁNDEZ-GUERRERO[1]

Laboratorio de Macroalgas
Departamento de Desarrollo de Tecnologías
Centro Interdisciplinario de Ciencias Marinas-IPN
Apdo. Postal 592, La Paz, Baja California Sur 23000, México
Tel. 12 25 344 ext. 82411 mmcasas@ipn.mx

CASAS-VALDEZ, M.; E. SERVIERE-ZARAGOZA, S. ORTEGA-GARCÍA, D. LORA-SÁNCHEZ and C. J. HERNÁNDEZ-GUERRERO, 2001. The harvest per unit effort (cpue) of *Gelidium robustum* along Baja California Peninsula and its relationship with temperature and upwelling. *An. Esc. nac. Cienc. biol., Méx.*, **47(1)**:73-83.

ABSTRACT: *Gelidium robustum* is the second most important algal resource in Mexico and its production represent 10% of world's production of agarophytes. This study analyses the trend of the harvest of *Gelidium robustum* in Mexico, compare both harvest and harvest per unit effort (cpue) in six zones of exploitation, and to describe the relationship between cpue with both temperature and upwelling. In Mexico the development of the exploitation of *Gelidium robustum* follows the typical pattern of a fishery. This fishery does not show any symptoms of overexploitation. The average harvest in the zone of Isla Natividad to Bahía Tortugas (294 t) and Isla Cedros (214 t) were significantly different to the other four zones and among them. The maximum harvest per unit effort (cpue) was found at Isla Cedros (4,038 kg/boat) and it is significantly different from the other five zones. A negative relation between cpue of *Gelidium robustum* and temperature was found in the northern, center and southern regions of Baja California Peninsula from 1985 to 1997. While a positive relation between cpue of *Gelidium* and upwelling index was found for the same regions.

INTRODUCTION

Gelidium robustum (Gardner) is, saxicolous and frequent ranging from British Columbia to northern California, it is common through the remainder of California to Isla Magdalena, Baja California Sur (Abbott & Hollenberg, 1976). On the Pacific coast of the Baja California Peninsula the species inhabits rocky shores exposed to strong waves from the mid level intertidal zone to a depth of 15–17 m (Guzmán del Próo and De la Campa, 1972).

Knowledge of the biology and ecology of *G. robustum* from Mexican Pacific coasts includes information from the central part of the Baja California, mainly studies of reproduction (Rodríguez and Espinoza, 1987; Espinoza-Ávalos, 1996), agar yield and gel strength (Espinoza and Rodríguez, 1992; Freile *et al.*, 1999). For the northern area, studies of growth and population structure (Guzmán del Próo and De la Campa, 1979; Castro and Uribe, 1987; Pacheco-Ruiz and Zertuche-González, 1995) and reproduction (Guzmán del Próo and De la Campa, 1972) have been reported. Guzmán del Próo *et al.* (1986) presented a description of the habitat and distribution.

Gelidium robustum is one of the most important species of agarophyta in the world for agar production. It is considered the best raw material because of the high quality of its agar (Armisen, 1995). Mexico is the fifth-largest producer; because it provides 10% of world's production of agarophytes (McHugh, 1991). *Gelidium robustum* is the second most important algal resource after *Macrocystis pyrifera* (L.) C. Agardh in Mexico. It has a high economic value and it is used to produce agar in the only company that produces phycocolloids in Mexico.

Along the western coast of Baja California Peninsula *Gelidium robustum* has been harvested continuously from 1956 along the western coast of Baja California Peninsula from Punta Descanso, B. C. (32°15′49" N and 117°1′16" W) to Punta Prieta, B. C. S. (27°0′50" N and 114°2′12" W). It is gathered by direct harvesting of the beds by hand picking (plucking) by diving between 5 to 15 m using an air compressor on the boat to supply air (Hooka). There is no management regulations for its exploitation (Zertuche-González, 1993), there has always been an official norm in which point out that the harvester must register their harvest volume and effort, the later has been registered in a regular manner since 1985.

The commercial harvest of *Gelidium robustum* and its relationship to some environmental variables have been analysed in some localities at the southern, limit of its exploitation (Casas-Valdez and Fajardo-León, 1990; Casas-

[1] Centro Interdisciplinario de Ciencias Marinas-IPN.
[2] Centro de Investigaciones Biológicas del Noroeste.
[3] Agarmex, S.A. de C.V.
[4] Becario COFAA-IPN
[5] Estudiante del PICP de la Universidad de Colima.

Valdez and Hernández-Guerrero, 1996; Hernández-Guerrero *et al*., 1999, 2000), but they haven´t been investigated along the Baja California Peninsula. The aim of this study is to analyze the trend of harvest of *Gelidium robustum* in Mexico, to compare both harvest and harvest per unit effort (cpue) in the six zones of exploitation, and to determine the relationship between cpue and both temperature and upwelling.

Material and methods

Harvest data

To analyze the trend of the historical production of *Gelidium robustum* in Mexico from the years 1956 to 1998 the harvest data were obtained from Guzmán del Próo *et al*. (1986), Casas-Valdez y Hernández-Guerrero (1996). This information was completed with data from the "Anuarios Estadísticos de Pesca" from 1996 to 1998. These harvest data include the total production (volume of harvest) of all the harvesters of *Gelidium robustum* along the Baja California Peninsula.

The harvest records of *Gelidium robustum* were obtained from the company Agarmex, SA de CV to study the annual trend of harvest, effort, harvest per unit of effort (cpue) for the period from 1985 to 1997 in the harvest zones of the Baja California Peninsula. The records contain: harvest date, place of harvest, harvest size in kilograms (dry weight), and number of boats. The original information comes from six harvest zones: *a*) Zone 1: Punta Descanso to Punta Banda; *b*) Zone 2: Santo Tomás to El Socorro; *c*) Zone 3: San Carlos to Punta Santa Rosaliíta; *d*) Zone 4: Isla Cedros; *e*) Zone 5: Isla Natividad to Bahía Tortugas and *f*) Zone 6: Morro Hermoso to Punta Prieta (Fig. 1).

Harvest per unit effort

The harvest per unit effort (cpue) has been used as an index of abundance in different commercial resources and seaweeds (Gulland, 1977; Pringle, 1981; Hilborn and Walters, 1992). The cpue was estimated for every zone as:

$$\text{cpue} = c/f$$

Where: c = harvest size in kilograms (dry weight), f = effort.

The unit of effort selected was the fishing equipment (a boat with three fishermen) and the harvest per unit effort (cpue) was expressed as harvest/boat.

With the propose to determine if there was a significant difference of the annual values of harvest, effort, and cpue for the period of 1985 to 1997 among the six exploitation zones they were compared through one-way ANOVAs (Zar, 1984). The significant differences between pairs of zones were analyzed by means of a Tukey test (Statsoft, 1999).

Environmental variables

Sea surface temperatures (SST) were obtained from the data base of Reynolds and Smith (1994). They contain monthly averages of sea surface temperature (°C) from 1985 to 1997 in 2° × 2° ocean quadrants. Records for latitudes 26°-28°, 28° - 30° and 30°-32° N were selected.

The upwelling index (UI) for latitudes 25.5°-28.5° and 28.5°-31.5° N for the period 1985 to 1997 were obtained from the upwelling index data base of Bakun, which maintain such records for 3° × 3° ocean quadrants. The upwelling index is expressed as $m^3 s^{-1} 100\ m^{-1}$ of coast (it is related to Ekman transport off the coast) (Bakun, 1973).

Relation of cpue with environmental variables

With the values of the series of harvest per unit effort, sea surface temperature and upwelling index were calculated the seasonal anomalies (the deviation of the value to respect of the average value for the period analyzed) using the equations,

$$A_{ij} = X_{ij} - \overline{X}$$

$$\overline{X} = \sum_{i=1}^{n} X_{ij} \Big/ n$$

where: A is the anomaly of the ith season of the jth year, X_{ij} is the ith season value of the jth year, $\overline{X}$ is the average value for the season i of n years.

To eliminate extreme values in the graphic representation, the series were softened using the movile technique.

The relationship between variations in the abundance (cpue) of *G. robustum* and the environmental variables was determined by cross-correlation using the seasonal anomalies of variables and harvest per unit effort. This analysis took into consideration the possibility of a lag period between algal responses and the environmental change (Anderson, 1972).

Results

Baja California Peninsula harvest

Harvest of *Gelidium robustum* has been consistent since 1956 along the west coast of Baja California Peninsula by different producers, such as the Sociedades Cooperativas de Producción Pesquera, Agarmex, and twelve other small companies. The historical series of harvest show four principal periods; the first of low harvest from 1956 to 1972, the second of high expansion of the fishery from 1973 to 1977, the third of a declination from 1978 to 1980 and the last one of stable harvest from 1981 to 1998 (Fig. 2). The high harvest of 1967 corresponded to a large increase in the international demand of *Gelidium*. We do not have an explanation for the extremely high harvest of 1977, it may be a result of a change in the register form, and it will be considered with caution.

Harvest, effort and cpue by zone

The annual values of harvest, effort and cpue estimated for the period 1985-1997 in the six zones show: zone 1 presented similar interannual variations in harvest and effort, both decreased slowly from 1985 to 1995 (Fig. 3a). This same pattern was found in zone 2 (Fig. 3b). The average harvest and effort in zone 1 was 31 tons and 43 boats and for zone 2 was 98 t and 76 boats. In zone 3, a general decreasing trend in harvest and effort was observed from 1985 to 1996. The harvest and effort average were 51 t and 36 boats (Fig. 3c). On the contrary, in zone 4, there was a clear increasing of both harvest and effort from 1985 to 1997. In this period, the harvest and effort average were 214 t and 53 boats (Fig. 3d). In zone 5 harvest and effort shows a great variability. Both harvest and effort decreased from 1985 to 1987, but increased during 1988 and 1989. From that year, harvest decreased until 1997 and effort was changing. Harvest and effort averages were 294 t and 194 boats (Fig. 3e). In zone 6, there was an increase in both the harvest and effort from 1986 to 1990-1991, decreasing during 1993-1994, and increasing from 1995 to 1997. Harvest and effort averages were of 50 t and 38 boats (Fig. 3f).

The average harvest in zone 5 (294 t) and zone 4 (214 t) were significantly different ($F_{(5, 69)} = 39.33$; $p < 0.05$) from the other four zones and among them. The fishing effort in zone 5 has been the largest (194 boats on average). This was significantly different ($F_{(5, 69)} = 49.77$; $p < 0.05$) from those of the other five zones.

The cpue in zone 1 was almost stable from 1985 to 1991, with average value of 721 kg/boat (Fig. 3a). In zone 2, the cpue had the same trend as that of zone 1; with an average value of 1,289 kg/boat (Fig. 3b). The cpue in zone 3 had two evident cycles 8 with maximum values in 1986 and 1992, and an average value of 1,416 kg/boat 8 (Fig. 3c). On the other hand, in zone 4 there was an increase in the cpue from 1985 to 1988. From that year until 1996, the cpue was an average of 4,038 kg/boat (Fig. 3d). The cpue in zone 5 increased gradually from 1985 to 1990 and then there was a gradual decrease until 1995. Subsequently it increased slightly in 1996-1997. The average cpue was 1,515 kg/boat (Fig. 3e). In zone 6, there was variability in the cpue. It had three peaks in 1985, 1992 and 1996. The average cpue was 1,316 kg/boat (Fig. 3f).

The maximum cpue was found at Isla Cedros (4,038 kg/boat) and it is significantly different ($F_{(5, 69)} = 69.13$; $p < 0.05$) from the other five zones.

The contribution of every zone to national production is different because of their harvested volumes. Zone 5 produces 36.5%, zone 4 (Isla Cedros) 30.5%, zone 2 produce 14.5%, zones 6 and 3 7.5% and 7%, and zone 1 4%. The magnitude of the effort is not always in the same order, except zone 5 that had the largest values.

Environmental variables

The values minimum, maximum, average and standar deviation of sea surface temperature and upwelling index on the west cost of the Baja California Peninsula are shown in table 1.

Relationship between cpue and environmental variables

Since the ANOVA results showed no significant difference between zones 1 and 2 and between zones 5 and 6. This allowed to group zone 1 and 2 in north region and zones 5 and 6 in a south region, for the cross-correlation analyzes. Zone 3 and 4 were significantly different ($F_{(5, 69)} = 69.13$; $p < 0.05$), and they were not grouped.

Particularly for the zone 3 and 4 this analysis was done using the periods of 1985-1998 and 1993-1997 respectively, because there was a continuity in the data to obtain the seasonal anomalies only in these periods.

Cross-correlation analysis between the abundance of *Gelidium robustum* and environmental variables showed a negative relation between *Gelidium* cpue and sea surface temperature in the northern region ($r^2 = -0.46$; $p < 0.05$) with a lag of five seasons (15 months) (Fig. 4a). Zone 4 ($r^2 = -0.61$; $p < 0.05$) had no lag (Fig. 4b), and in the southern region ($r^2 = -0.44$; $p < 0.05$) with a lag of five seasons (Fig. 4c). Higher temperatures are associated with lower abundance. The correlation between cpue and temperature was no significant in zone 3.

The relationship was positive with upwelling index in the northern region ($r^2 = 0.54$; $p < 0.05$) with a lag of five seasons (Fig. 4d). Zone 4 ($r^2 = 0.46$; $p < 0.05$) had no lag (Fig. 4e), and in the southern region ($r^2 = 0.36$; $p < 0.05$) with a lag of five seasons (Fig. 4f). Increased of upwelling is related to higher abundance. The correlation between cpue and upwelling was no significant in zone 3.

Discussion

Harvest, effort and cpue

The cpue has been used as an accepted index of resource abundance in seaweeds (Pringle, 1981; Hernández-Guerrero *et al.*, 1999). In this study the data of harvest and effort used to estimate the cpue are trustworthy and reflect the abundance because of the following: 1. The company that provided harvest and effort records for the analysis by zones has harvested 92% of the total production of the northern region, 79% of the central region and 84% of the southern region 2. The company works only on the extraction and industrialization of *Gelidium* along the year. They have no alternative resources as does the Sociedades Cooperativas de Producción Pesquera or other small companies that harvest *Gelidium* and 3. The price variations of the seaweed do not influence on the harvest intensity in the company.

Nevertheless, because of the harvest strategy, a more reliable indicator of the effort would be the number of trips or the diving time, as suggested by Casas-Valdez and Hernández-Guerrero (1996). Likewise, it is especially important the accuracy in the records (number of boats and place where the effort was applied) in order to the cpue to truly reflect the abundance of the resource.

The maximum and minimum values of cpue were found in zone 4 and zone 1, respectively. Such values coincide with the available biomass data reported by Castro and Uribe (1987). They also found a maximum biomass in zone 4 (4.5 kg/m²), and the minimum in zone 1 (1.5 kg/m²). Additionally, this coincides with the contribution per zone to the total production, zone 4 contribute with 30%, while zone 1 only with 4%.

The decrease of harvest and effort in zones 1, 2 and 3 and the increase in zone 4 from 1985 to 1996, are due to a temporary strategy of the producers. Our results showed that the cpue has been stable in the four zones. Then, conside-ring that this is an index of abundance, it is possible to think that the abundance in these zones was not affected by the intensity of the fishing effort. While in zone 5 the effort was almost constant; the cpue presented a decreased tendency since 1989 which could indicate a diminishing of the resour-ce abundance. The effect of the variability of the applied effort was observed in zone 6, where the harvest is not regular during the year and over the years.

Relationship between cpue and environmental variables

Temperature has a direct effect on organisms; particularly for *Gelidium* species this has influenced on the growth rate, regrowth, reproduction, and abundance (Santelices, 1991).

In this work a negative relation between cpue of *Gelidium robustum* and temperature was found in the northern, center and southern regions of Baja California Peninsula from 1985 to 1997. We believe it happens because an important part of this period (1992-1997) was a warm period that occurred along the Baja California Peninsula. In the three zones a negative relation was found, although there are differences in temperature (minimum, maximum, and average) among them, the pattern of interannual variations was similar. This result agrees with Hernández-Guerrero *et al.* (2000) who found a negative relation during El Niño, a warm year (August 1982-October 1984) between tempe-rature and cpue of *Gelidium robustum* at the southern limit of its distribution in the Baja California Peninsula. While a positive relation was found during La Niña, a cold year (November 1987-March 1989), and in normal years (No-vember 1984-October 1987).

In this respect Borja (1994a) found a direct relation (r = 0.77) between biomass of *G. sesquipedale* and temperature during normal environmental conditions. Barilotti and Silverthorn (1972) also mentioned that the increase in growth rate of *G. robustum* was related to the increase in temperature.

The upwelling index, an indicator of Ekman transport which brought to the surface deep waters rich in nutrients, plays an important role in the production cycles in the sea (Mann and Lazier, 1991). The species of *Gelidium* are more productive in rich nutrients water (Santelices, 1991). It was found a positive relation between cpue of *Gelidium* and upwelling index in the northern, center and southern regions of the Baja California Peninsula. High values of the upwelling index mean larger amounts of nutrients (nitrates, phosphates). A similar relation was found between upwelling and cpue in the three regions, because the pattern of interannual variations is similar among them. This agrees with the results of Hernández-Guerrero *et al.* (2000) whose found a positive relation between the interannual variation of the cpue of *G. robustum* and the upwelling index at the southern limit of its distribution in three periods (La Niña, normal conditions and El Niño).

The relationship between cpue of *Gelidium robustum* and both temperature and upwelling was similar between zones, but with different lag periods. This may be related to differences in the periodicity of the harvest. Although the harvest of *Gelidium* is similar in all areas, however, the beds are harvested every 3, 4, 5, or 6 months or one year in the different zones and it can change from one year to another in the same zone. Because of that, it was not possible to define or establish a periodicity for the *Gelidium* harvest by regions or zones or in different years. Likewise, the *Gelidium* fishermen point out that they can came back to harvest a bed in 3-6 months. It depends of every bed, there are beds in which the development is faster than others. With respect to this Santelices (1991) noted that the growth rate of *Gelidium* depends on the specific environmental conditions of its location. The regrowth of the beds along Baja California Peninsula must have differences and it was reflected in the harvest at different times. This emphasizes the necessity of the use of binnacle to record with precision the place of harvest and the effort used. For beds of *G. sesquipedale* along the coast of Spain, the regrowth is reached in 9 months to one year (Seaone-Camba, 1966; Cendreros and Ramos, 1967; Juanes and Borja, 1991; Borja, 1994b) or two years (Gorostiaga, 1990). Carter and Simons (1987) found for *G. pristoides* from Port Alfred, South Africa that after 12 weeks of regrowth, the yields were larger than obtained in the initial harvest.

In general, the development of the exploitation of *Gelidium robustum* in Mexico follows the typical pattern of a fishery (Fig. 2); an initiation stage with low harvest (in this stage the fishermen are acquiring experience in the extraction of the resource), followed by an increase of the harvest as a result of the expansion of the fishery, then a decline, and later on a stage of stabilization where the fishery is consolidated (Hilborn and Walters, 1992). Then and according to our results in which the cpue values have been stable (except in zone 5) we could consider that the fishery does not present symptoms of overexploitation.

Finally, although at present the fishery of *Gelidium* does not show overexploitation, it is necessary to make systematic studies of growth, reproduction, recruitment, regrowth, biomass, productivity, harvest, effort, catch per unit effort, yield, and quality of agar along the Baja California Peninsula to have a scientifically-based resource management program, to maintain maximum sustainable yields.

Resumen

Gelidium robustum es el segundo recurso algal más importante de México, los volúmenes cosechados representan el 10% de la producción mundial de agarofitas. En este trabajo se analiza la tendencia de la cosecha de *Gelidium robustum* en México, se comparan tanto la cosecha como la cosecha por unidad de esfuerzo (cpue) en seis zonas de explotación y se presenta también la relación encontrada entre la cpue y la temperatura y los índices de surgencia. En México el desarrollo de la explotación de *Gelidium robustum* sigue el patrón típico de una pesquería y no muestra síntomas de sobreexplotación. La cosecha promedio en la zona de Isla Natividad a Bahía Tortugas (294 t) e Isla Cedros (214 t) fue significativamente diferente a las otras cuatro zonas y entre ellas. La máxima cosecha por unidad de esfuerzo (cpue) se encontró en Isla Cedros (4,038 kg/equipo) y fue significativamente diferente a las otras cinco zonas. Se encontró una relación negativa entre la cpue de *Gelidium* y la temperatura en las regiones norte, centro y sur de la península de Baja California en el periodo de 1985 a 1997. Mientras que se encontró una relación positiva entre la cpue de *Gelidium* y los índices de surgencia para las mismas regiones.

Acknowledgments

Thanks to Agarmex, SA de CV for providing tha data harvest of *Gelidium robustum*. The comments of two anonymous reviewers greatly helped to improve the manuscript.

Bibliography

ABBOTT, I. A. and HOLLENBERG, G. J., 1976. *Marine Algae of California*. Stanford University Press, Stanford.

ANDERSON, T. W., 1972. *The Statistical Analysis of Time Series*. John Wiley & Sons, Inc. U.S.A.

ARMISEN, R., 1995. Worldwide use and importance of *Gracilaria*. *Journal of Applied Phycology*, **7**:213-243.

BAKUN, A., 1973. Coastal upwelling indices, west coast of North America, 1946-71, U.S. Dept. Commer. NOAA Tech. Rep. NMFS SSRF-671.

BARILOTTI, S. D. and SILVERTHORNE, W., 1972. A Resource Management Study of *Gelidium robustum*. *Proc. Int. Seaweed Symp.*, **7**:255-261.

BORJA, A., 1994a. Factores ambientales que influyen en el crecimiento, producción y desprendimiento de biomasa en praderas naturales de *Gelidium sesquipedale* (Clem.) Born. Et Thur. en el país Vasco (N de España). *Sci. Mar.*, **58(3)**:251-260.

______, 1994b. Impacto de la cosecha y recuperación de la biomasa del alga *Gelidium sesquipedale* sometida a dos formas de explotación en el país Vasco (España). *Aquat. Living Resour.*, **7**:59-66.

CARTER, A. R. and SIMON, R. H., 1987. Regrowth and Production Capacity of *Gelidium pristoides* (Gelidiales, Rhodophyta) under Various Harvesting Regimes at Port Alfred, South Africa. *Botánica Marina*, **30**:227-231.

CASAS-VALDEZ, M. and FAJARDO-LEÓN, C., 1990. Análisis preliminar de la explotación de *Gelidium robustum* Hollenberg y Abbott en Baja California Sur, México. *Inv. Mar. CICIMAR*, **5(1)**:83-87.

CASAS-VALDEZ, M. and HERNÁNDEZ-GUERRERO, C. J., 1996. Pesquería de *Gelidium robustum*, pp: 419-429. In: M. Casas Valdez y G. Ponce Díaz (eds.) Estudio del Potencial Pesquero y Acuícola de Baja California Sur. SEMARNAP, Gobierno del Estado de Baja California Sur, FAO, Instituto Nacional de la Pesca, UABCS, CIBNOR, CICIMAR, CET del MAR.

CASTRO; L. R. and URIBE, O. F., 1987. Estudios de manejo del recurso *Gelidium robustum* (Gelidiaceae: Rhodophyta) en Baja California. 1.2 Biomasa disponible en Punta San Miguel y en ocho zonas sujetas a explotación. *Memorias del Congreso de Oceanografía*, pp. 59-71.

CENDREROS, O. and RAMOS, F., 1967. Trabajos sobre las algas del género *Gelidium* en la provincia de Santander. *Publ. Téc. Junta Est. Pesca*, **6**:283-290.

ESPINOZA-ÁVALOS, J., 1996. Estructura de tallas y reproducción de *Gelidium robustum* (Rhodophyta) en la parte central de la Península de Baja California, México. *Ciencias Marinas*, **22(4)**:415-426.

ESPINOZA, A. J. and RODRÍGUEZ, H., 1992. Rendimiento y fuerza de gel de *Gelidium robustum* (Gelidiales, Rhodophyta) de la parte central de la Península de Baja California. *Rev. Inv. Cient.*, **3(1)**:1-10.

FREILE-PELERIN, Y.; D. ROBLEDO and SERVIERE-ZARAGOZA, E., 1999. *Gelidium robustum* agar: quality characteristics from exploited beds and seasonality from an unexploited bed at Southern Baja California, México. *Hydrobiologia*, **398/399**:501-507.

GOROSTIAGA, J. M., 1990. Aspectos demográficos del alga *Gelidium sesquipedale* (Clem.) Born. Et Thur. Discusión sobre su adecuada gestión como recurso explotable. Tesis doctoral. Universidad del País Vasco. España.

GULLAND, J. A., 1977. The analisis of data and development of models, pp: 72-95. In: J. A. GULLAND (ed.). Fish Population Dynamics, Wiley. USA.

GUZMÁN DEL PRÓO, S. and DE LA CAMPA, S., 1972. Shedding rhythm and germination of spores in *Gelidium robustum*. *Inter. Seaweed Symp.*, **7**:221-228.

______, 1979. *Gelidium robustum* (Florideophyceae), an agarophyte of Baja California, Mexico. *Proc. Int. Seaweed Symp.*, **9**:303-308.

GUZMÁN DEL PRÓO, S.; M. CASAS-VALDEZ, A. DÍAZ-CARRILLO, M. L. DÍAZ-LÓPEZ, J. PINEDA-BARRERA and SÁNCHEZ-RODRÍGUEZ, M. E., 1986. Diagnóstico sobre las investigaciones y explotación de las algas marinas en México. *Investigaciones Marinas CICIMAR*, **3(2)**:1-63.

HERNÁNDEZ-GUERRERO, C. J.; M. CASAS-VALDEZ and ORTEGA-GARCÍA, S., 1999. Cosecha Comercial del alga roja *Gelidium robustum* en Baja California Sur, México. *Revista de Biología Marina y Oceanografía*, **34(1)**:91-97.

HERNÁNDEZ-GUERRERO, C. J.; M. CASAS-VALDEZ, ORTEGA-GARCÍA, S. and HERNÁNDEZ-VÁZQUEZ, S., 2000. Effect of climatic variation on the relative abundance of the red alga *Gelidium robustum* in Baja California Sur, Mexico. *Journal of Applied Phycology*, **12**:177-183.

HILBORN, R. and WALTERS, C. J., 1992. Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty. Chapman & Hall, Inc. USA.

JUANES, J. A. and BORJA, A., 1991. Biological criteria for the exploitation of the commercially important species of *Gelidium* in Spain. *Hydrobiologia,* **221**:45-54.

MANN, K. H. and LAZIER, J. R. N., 1991. Dynamics of Marine Ecosystems Biological-Physical Interactions in the Oceans. Blackwell Sci. Publs. Boston.

MCHUGH, D. J., 1991. Worldwide distribution of commercial resources of seaweeds including *Gelidium,* pp:19-30. In: JUANES, J. A., B. SANTELICES & J. L. MC LACHLAN (eds.). International Workshop on *Gelidium.* Kluwer Academic Publishers, The Netherlands.

PACHECO-RUIZ, I. and J. ZERTUCHE-GONZÁLEZ, 1995. Efecto del movimiento del agua sobre el crecimiento de *Gelidium robustum* (Gardn.) Hollenb. y Abb. (Rhodophyta). *Ciencias Marinas,* **21(1)**:59-70.

PRINGLE, J. D., 1981. The relationship between annual landings of *Chondrus* dragrakers, effort, and standing crop in the southern Gulf of St. Lawrence. *Proc. Int. Seaweed Symp.*, **10**:719-724.

REYNOLDS, R. W. and SMITH, T. M., 1994. Improved global sea superface temperature analyses. *J. Climate,* **7**:929-948.

RODRÍGUEZ, H. and ESPINOZA, J., 1987. Variación de las fases reproductivas de *Gelidium robustum* (Gard.) Holl. y Abbott en siete mantos algales de la Península de Baja California, México. *Inv. Mar. CICIMAR*, **3**:79-86.

SANTELICES, B., 1991. Production ecology *Gelidium. Hydrobiologia,* **221**:31-44.

SEOANE-CAMBA, J., 1966. Algunos datos de interés en la recolección de *Gelidium sesquipedale. Publ. Tecn. J. Est. Pesca*, 5:437-455.

STATSOFF INC., 1999. Statistic for windows. Computer Program Manual, Tulsa, USA.

ZAR, J. H., 1984. Bioestatistical Analisis. 2°ed. Prentice-Hall, Inc. Englewood Clifts, N J, USA.

ZERTUCHE-GONZÁLEZ, J. A., 1993. Situación actual de la industria de las algas marinas productoras de ficocoloides en México, pp: 33-38. In J. A. Zertuche-González (ed.). Situación actual de la industria de macroalgas productoras de ficocoloides en América Latina y el Caribe. Documento de Campo No. 13. FAO. México.

TABLE 1. Minimum, maximum, average and standar deviation values of sea surface temperature and upwelling index for the region north, center and south.

	Temperature (°C)			Upwelling ($m^3s^{-1}100\ m^{-1}$)	
	30°-32° N	28°-30° N	26°-28° N	28.5°-31.5° N	25.5°-28.5° N
Minimum	16.89	17.73	17.87	91.08	77.58
Maximium	19.28	20.03	21.87	134.50	129.00
Average	17.90	18.44	19.57	116.44	108.58
Standar Dev.	0.68	0.68	1.28	11.82	16.98

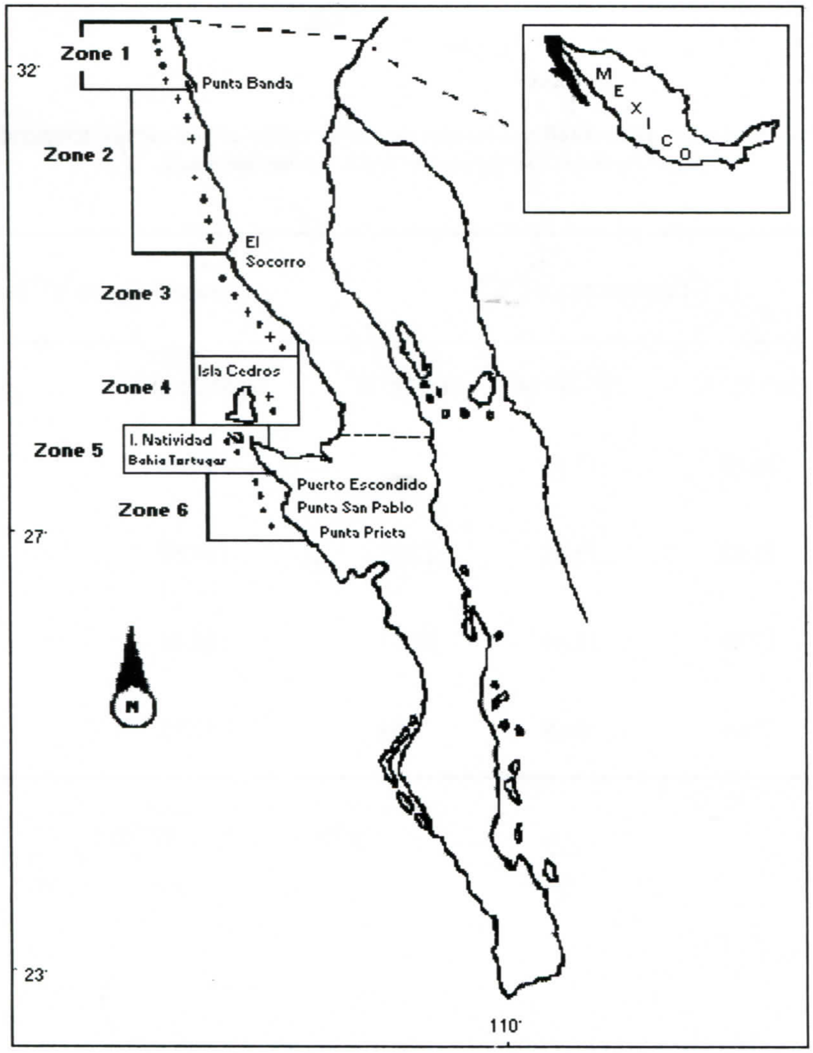

FIG. 1. Harvest zones of *Gelidium robustum* in Baja California Peninsula.

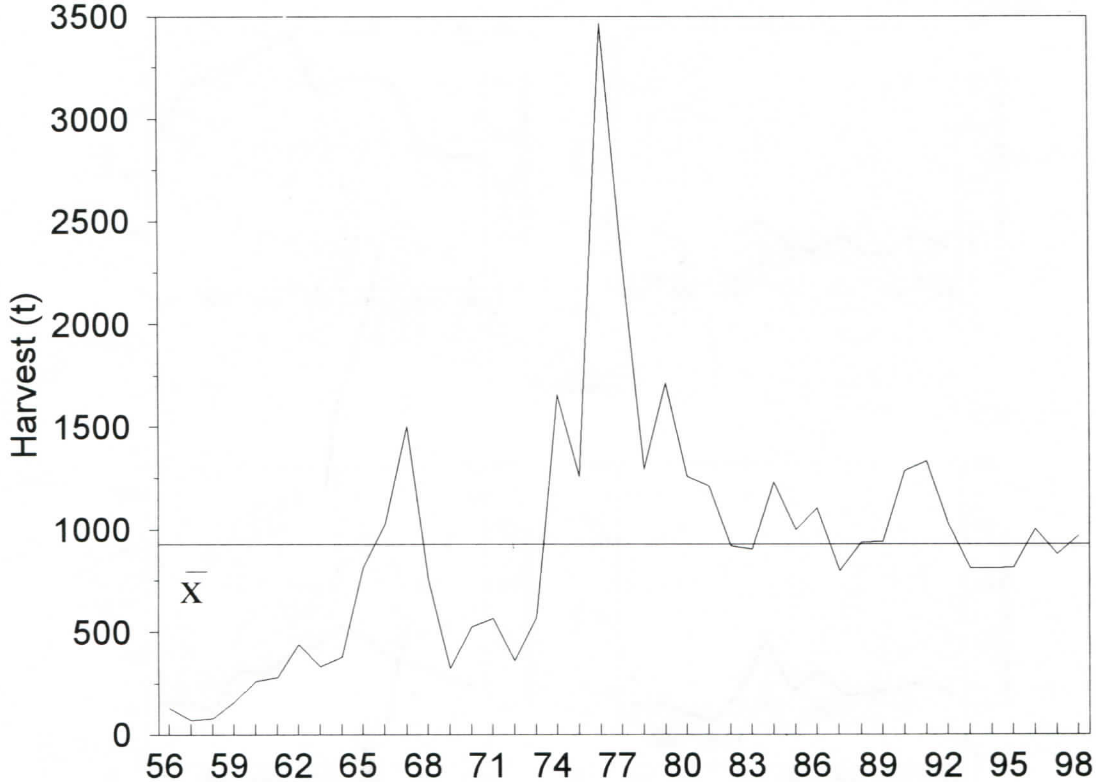

FIG. 2. Harvest of *Gelidium robustum* in Baja California Peninsula.

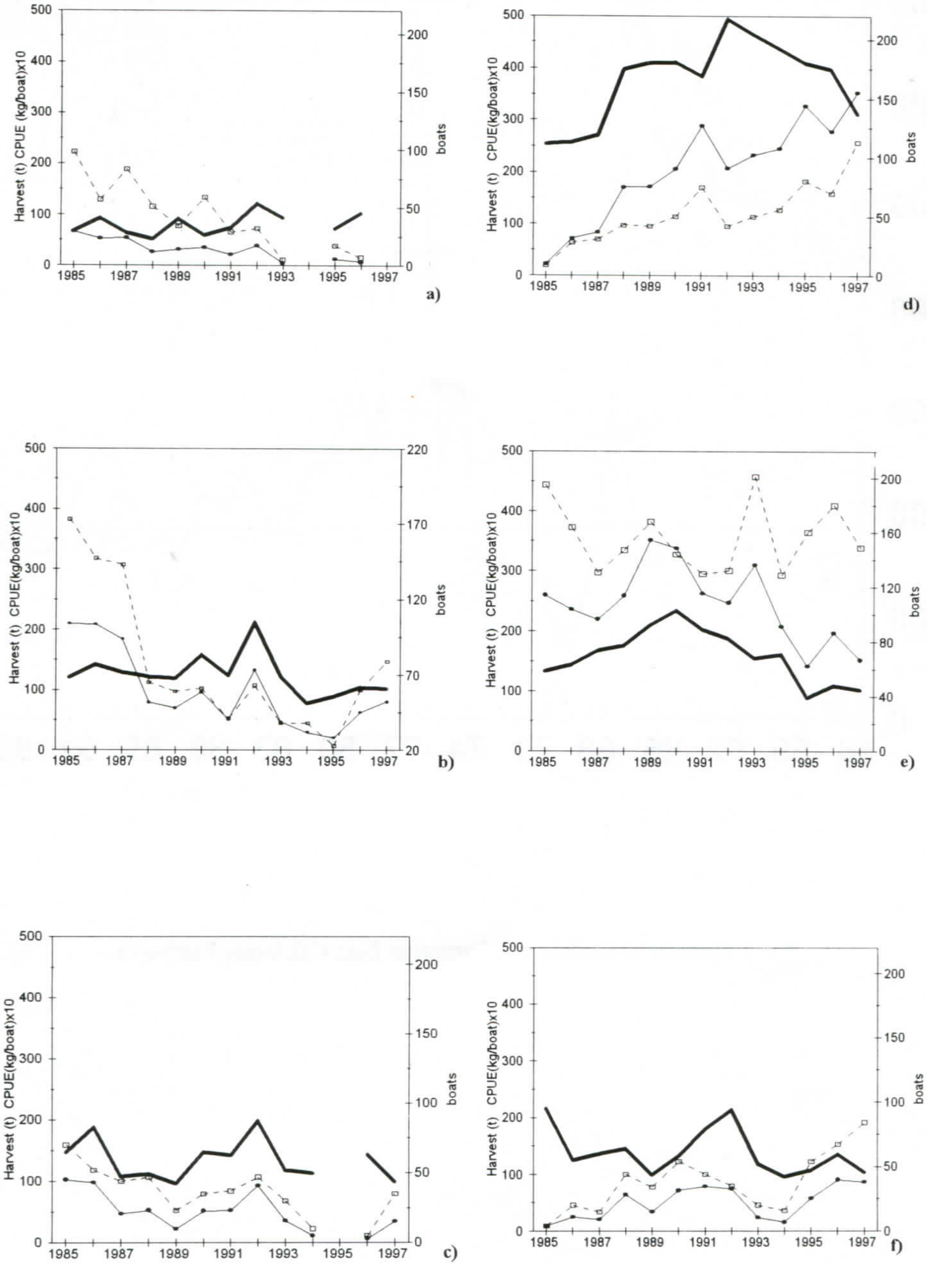

FIG. 3. Harvest, effort and harvest per unit effort (cpue) of *Gelidium robustum* in a) zone 1 (Punta Descanso to Punta Banda), b) zone 2 (Santo Tomás to El Socorro), c) zone 3 (San Carlos to Punta Santa Rosaliíta), d) zone 4 (Isla Cedros), e) zone 5 (Isla Natividad to Bahía Tortugas) and f) zone 6 (Morro Hermoso to Punta Prieta). —·— Harvest, --□-- Effort, — cpue.

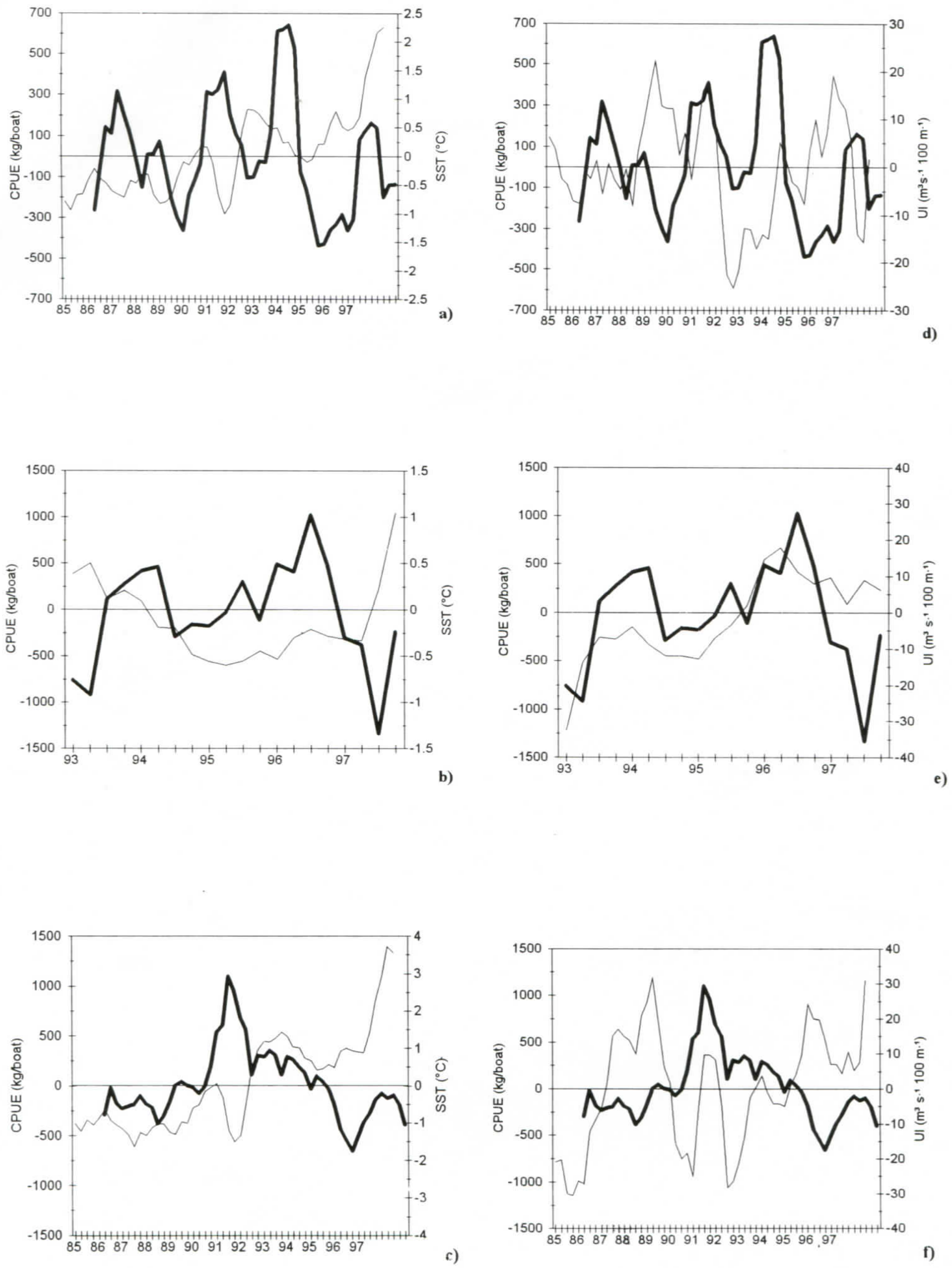

FIG. 4. Anomalies of cpue of *Gelidium robustum* and sea surface temperature in *a*) northern region, *b*) Isla Cedros, *c*) southern region and upwelling index in *d*) northern region, *e*) Isla Cedros and *f*) southern region. The cpue was lag five seasons. The heavy line represents cpue of *Gelidium robustum* and the thin line represents the environmental variable.

Recibido: diciembre de 2000 Aceptado: junio de 2001.