Assessment of the Queen conch *Strombus gigas* (Gastropoda: Strombidae) Population in Cayos Cochinos, Honduras*

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Abstract: A visual preliminary assessment of the *Strombus gigas* population in the area of the Cayos Cochinos Biological Reserve was conducted by SCUBA divers swimming transects. Additional data on size/age structure, morphometries (shell length, shell width, shell lip thickness, and total weight), habitat, and reproductive activity were also collected. Size frequency distributions are given for shell length and shell lip thickness in an effort to reveal growth and age of the various cohorts. Linear regression analyses were conducted between various morphometric measurements. A total of 40 transects were completed covering a total area of 45504 m2. The mean area of a transect was 1137.6 m2 at a mean depth of 15.3 m. The overall density was calculated as being 14.6 conch/ha (S.D. = 36.15) over the study area of 15330 ha giving an approximate total abundance of 223818 conch. The majority (58.8%) of conch found in transects were found in depths of less than 10 m. A total of 177 conch were collected in and out of the transects with 48% juveniles and 52% adults. The population was further sub-divided into six categories for quick assessment during transects: four juvenile; small (0%), medium (10.7%), large (19.8%), sub-adult (17.5%): and two adult normal (27.1%), and stoned (24.9%). Reproductive activity included copulation, spawning, and solitary egg masses concentrated on seagrass slopes from five to 18 m in depth. New details on copulation were observed. It is felt that the low density and abundance is a direct result of 30 years of heavy exploitation by the Garifuna fishermen and commercial divers prior to the creation of the reserve. Future management measures should include the increase of the minimum shell length restriction to 240 mm, the use of a mature lip regulation, banning of SCUBA in fishing, and seasonal closures of important breeding areas.

Key words: *Strombus gigas,* queen conch, population assessment, growth, reproduction, Honduras**.**

The queen conch, *Strombus gigas* Linnaeus, 1758, is a large marine gastropod mollusk of the order Mesogastropoda and is one of seven species of the family Strombidae occurring in the Western Atlantic. It has long been valued for meat and shell and has been fished since prehistoric times (Brownell *et al.* 1977, Berg & Olsen 1989). A sizable commercial fishery has developed over the last 25 years. This is due to the increasing demand for conch internationally as well as the demands by growing populations of natives and tourists in the region. Once common in shallow waters, conch are now caught in ever increasing depths by fishermen equipped with SCUBA and Hookah gear in place of traditional conch hooks and free-diving techniques. The most up-to-date figs. for regional conch harvest is just under 6000 MT annually (Tewfik 1995). Fears of the disappearance of commercial conch fisheries by some biologists have caused *S. gigas* to be included on appendix II of the Convention on the International Trade of Endangered Species (CITES). International trade of queen conch is therefore only allowed by permit from nations documenting that the exploited population is not threatened by commercial fishing.

With the recent designation of the Cayos Cochinos area as a biological reserve (1993) it seemed appropriate that an assessment of the queen conch population be undertaken. This assessment was limited in spatial (number of sites, 1/3 of reserve area) and temporal (single summer sampling) ranges and serves as a basis for further comprehensive investigations. The conch population has been under intense fishing pressure from the local Garifuna people, some based on cays within the reserve, for approximately 30 years. The assessment was to provide estimates of total abundance and density as well as a description of the size/age structure, morphometric analysis, relative distribution within habitats and depth, and identification of critical spawning areas and nursery grounds that may require special protection within the reserve. This information could also allow decisions to be made regarding potential rehabilitation of this critical tropical littoral species with regards to the basic ecology of the area and sustainable fisheries potential for the human population living within the reserve.

MATERIALS AND METHODS

The study was conducted in the area around Cayos Cochinos Biological Reserve located at 15? 59' N and 15?51' latitude and 86?25' W and 86?35' longitude, between July 18/96 and Aug. 6/96. These boundaries enclosed an area of approximately 153.3

km2 (1/3 of the reserve) (Fig. 1). The remaining area of the reserve is largely in excess of 30 m in depth and below the normal depth range of *S. gigas*. A 30 second latitude by 30 second longitude grid was placed over the US Government survey map No. 28154 (Approaches to La Ceiba). This allowed X and Y coordinates to be randomly selected to determine the preliminary start points of the survey transects. The start points were further adjusted to cover a wide range of depth and habitat types within the overall enclosed area of the study.

Visual assessment of queen conch by SCUBA divers has been done in a number of studies (Wood & Olsen 1983, Smith & Neirop 1984, Weil & Laughlin 1984, Berg *et al.* 1992a, Friedlander *et al.* 1994, Berg & Glazer 1995, Tewfik 1996) and is appropriate when dealing with clear waters with irregular bottom types. The actual transect was completed by two divers swimming with a 3 m long PVC bar, which determined the width of the transect, in a predetermined direction that would maintain or increase the depth along the transect. The chosen direction was maintained using a compass mounted on the PVC bar. The length of the transect was determined by taking two positions with a Magellan Global Positioning System (GPS) to the nearest second. Once the support boat was in the approximate area of the start point the weighted PVC bar was thrown overboard and allowed to sink to the bottom. The attached rope was brought perpendicular to the surface and the initial GPS reading taken. At the end of a transect the divers would leave the PVC bar on the bottom. Once on board the support vessel the final GPS reading was taken. The positions are accurate to within 30 m. The overall area surveyed by each transect was a simply calculation of length (GPS positions) multiplied by width (3 m bar).

During the transect swims all conch encountered within the three meter wide bar were recorded as one of six size/age categories onto a clipboard, equipped with underwater paper, attached to the bar. Although growth rates and subsequent sizes at specific ages vary with depth, latitude, and food resources throughout the region categories are based on mean values of shell lengths (juveniles) and shell morphologies (sub-adults, normal and stoned adults) described in the literature (Alcolado 1976, Berg 1976, Appeldoorn 1988a, Buckland 1989) and observed in the field (Tewfik 1996). The use of categories allowed a quick assessment of an individual conchís place within the population structure. The first three categories are for individuals without a flared lip (juveniles).

Fig. 1. Cayos Cochinos: location of sites surveyed.

The size of the juveniles was quickly determined by sizes marked on the three meter bar and are as follows: Small (Sm) < 150 mm, Medium (M) 150 - 200 mm, and Large (L) > 200 mm. The remaining categories are: Sub-Adult (SA) which are individuals with flared lips forming (immature) that are generally less than four mm in thickness; Normal Adult (N) having a fully formed broad but not overly thick lip with prominent spines, minor epibiotic fouling, and relatively smooth outer surface; and Stoned (Older) Adult (S) having a fairly thick, warn lip with fairly worn spines, sometimes heavy epibiotic fouling (sponges, corals, etc.), and rough outer surface. The term "Stoned" conch is used by Jamaican fishermen to describe those conch whose shells are more difficult to chop through and remove the meat because of the very thick shells (Tewfik 1996). All other conch seen outside the transect were noted and categorized but not included in data for abundance and density calculations. During the transect other data was collected including descriptions of habitat, initial and final depths (mean depth was used for site descriptions in Table 1), and observations of copulation, spawning, and solitary egg masses. The habitat types used, partially adapted from Smith and Nierop (1986), include: Algal Plain (AP) with substrate of various texture from fine mud to coarse sand dominated by green algae (*Halimeda, Penicillus, Caulerpa, Udotea, Rhipocehalus*); Reef (RF) which includes a variety of reef morphologies (heads, patch, fringing) and are dominated by large living colonies of stony corals of the head forming and branching types (*Acropora, Montastraea, Diploria*); Rock (R.) which are low relief, hard bottom and dead, eroded reefs dominated by soft corals, small solitary corals, and sponges with small areas occasionally covered by a thin layer of sediment where sea grasses and green algae may form patches; and Seagrass meadows (SG) where turtle (*Thalassia*) and manatee (*Syringodium*) grasses dominate on sediments of varying texture and depth.

All conch observed during transect swims, except copulating and spawning adults, were collected from the sea so that various morphometric measurements could be taken. Shell length (LTH) (tip of the spire to the siphonal canal) was measured to the nearest mm using a measuring board. The maximum width of the largest body whorl (WTH) (anterior base of the spine on the extreme right to the base of the spine on the extreme left) was measured using sliding vernier calipers to nearest 0.1 mm (Alcolado 1976). The shell lip thickness (LIP) (mid-lateral region on the lip side of the shell approximately 40 mm in from the edge of the shell) was measured to the nearest 0.1 mm also using sliding vernier calipers. Finally the total weight (wet) (TWT) was measured using a triple beam balance to the nearest gram. Once the measurements were completed all animals were returned to the sea and in most cases to the area of capture. The exceptions mentioned earlier (copulating and spawning adults) had only lip thickness measured as above in situ. The collection of these measurements would allow mean sizes to be established for the various parameters within the stock as well as the construction of size-frequency distributions of shell length and shell lip thickness. Standard linear regression techniques between Log_{10} transformations of the measurements were also done to establish relationships between the various parameters. Finally t-tests were run between the various parameters measured for both normal and stoned adults to find if there were true statistical differences between them due to the subjective nature of the categories (erosion, fouling, etc.). The differences between other categories was self evident due to length (maximum and/or minimum) and lip formation (present or not) criteria set at the beginning of the study.

RESULTS

A total of 40 transects (Fig. 1) were completed in 17 days of diving. The mean area of a transect was 1137.6 m^2 with a mean linear distance of 379.2 m. The mean depth of the transects was 15.3 m. A total of 45 504 m^2 was surveyed. A total of 47 conch were counted within 17 (42.5%) of the transects. Table 1 gives the mean density and standard deviation (S.D.) per hectare for each category and total conch as well as area sampled (m^2), mean depth, and habitats for each site. The overall Fig. of 14.6 conch/hectare (S.D.= 36.15) gives a total abundance of approximately 223818 conch over the 15330 ha (153.3 km^2) included in the study.

The population structure, when using the average density figs. per hectare (Table 1), changes with 49.3% juveniles and 50.7% adults. No small category juveniles were ever encountered. A total of 177 conch were collected in the field with 48.0% juveniles and 52.0% adults. Fig. 2 gives a complete breakdown of population structure by category for both conch found in transects and total individuals collected.

Fig. 2. Overall population structure, Cayos Cochinos, July 1996.

Fig. 3. Juvenile shell length-frequency distribution.

Fig. 4. Adult shell length-frequency distribution.

Fig. 5. Adult shell lip thickness-frequency distribution.

Size frequency distributions have been constructed for juvenile (M, L, SA) shell length (Fig. 3), adult (N,S) shell length (Fig. 4), and adult (N,S) shell lip thickness (Fig. 5).

With respect to habitat and depth conch were found in all but one habitat/depth type. No conch were found at any of the ten AP sites that were not associated with any other habitats with depths > 21 m. This constitutes 25.0% of the sites. 58.8% of conch were found in transects where depth was less than 10 m. Reproductive activity in the form of copulation, spawning, and solitary egg masses were observed at three sites which did have a more narrow range of habitat and depth. Site nine being a steep SG slope from 5 - 17 m had a total of 15 stoned conch, one pair copulating, and one female involved in spawning. Site 21 was a gentle sloping SG area (6 - 18 m) with a total of 19 adults (N-10, S-9). One pair, stoned, was involved in copulation, another stoned female was spawning, as well as the presence of a solitary egg mass. Finally, site 31 had a single S female spawning with 3 other S adults in a small sand patch amongst rock (R.). Small groups of stoned adult conch were observed at sites 48 (4 stoned at 26 m) and 57 (3 stoned at 23 m) both in AP sloping into deeper water (> 30 m) adjacent to RF habitats. However no reproductive activity was observed at these sites. Subsequent visit to site 9 in March of 1997 revealed the presence of 20 adult conchs, 3 with eggmasses, with lip thicknesses ranging from 11.5 to 26 mm. Three nursery areas were observed in and around sites 10, 16, and 32 all containing fair numbers of juveniles (M, L, SA) and all three sites contained healthy SG habitats between three and six meters in depth. (A subsequent visit to site 9 in March 1997 revealed presence of 20 adults (lip thicknesses 11.5-26.0 mm) on sand slope (9.7-14 m of which 3 had egg masses.)

Table 2 gives a summary of the general statistics for the morphometric measurements collected (LTH, WTH, LIP, TWT). Table 3 gives the summary of the results of linear regressions between various morphometric measurements. It should be noted that the strongest correlations were seen between measurements within juvenile specimens. The results of the t-tests between various parameters of normal and stoned categories are as follows: shell length, no significant difference ($t=0.572$, 54 d.f., $p=0.5700$); shell width, no significant difference ($t=-0.345$, 54 d.f., $p=0.7315$), shell lip thickness, significant difference (Mann-Whitney rank sum test, $p<0.0001$), and total weight, no significant difference ($t=-1.50$, 54 d.f., $p=0.1400$).

DISCUSSION

Visual data collection by SCUBA diver is the only real practical tool available to fisheries biologists in assessing large benthic stocks such as queen conch. The specific methodology used in this study was a compromise between available time, personal, and accuracy. The short duration and limited time of the study demanded that the maximum area be covered over a diversity of habitat and depths. The use of the GPS to calculate transect length allowed time consuming and cumbersome measurements with a tape to be avoided but allowed a greater area to be covered despite the small error in the GPS locations. Some other studies of this kind have used towed divers which disallow direct examination of the conch, which does not provide for accurate categorization, detailed observations on reproductive behavior, and simultaneous collection of specimens for further examination on shore. This study went beyond mere censuring of the stock and allowed for the preliminary examination of various aspects of conch biology including growth, habitat preferences, and reproductive biology.

The density reported (14.6 conch/ha, S.D. 36.15) is about average for studies of this type in the region (Table 4). The high standard deviation is a direct result of the high number of sites (57.5%) where no conch were reported. This is due partially to the patchy distribution of the conch mainly around Isla Cochino Pequeño where the presence of the marine laboratory and park ranger station provide a high level of protection within the larger reserve. The fairly low overall density and abundance can be directly attributed to the heavy artisinal fishing pressure by the local Garifuna people, based on cays within the reserve, and commercial diving over the last three decades on a stock which is largely quite accessible in waters less than 10 m deep.

The categories used in the study reflect the approximate age groups within the population. The juvenile categories of Sm, M, L, and SA represent 1+, 2+, 3+ and 4+ year old individuals, respectively. The population structure observed in both transects and total specimens collected is fairly evenly dispersed between five of the six categories (Fig. 2). The absence of Sm conch is not surprising due to the in faunal nature of these individuals during the first year after metamorphosis. Several authors have reported that conch of less than one year (0+ cohort) are rarely encountered (Randall 1964, Heese 1979) and are usually under sampled (Appeldoorn 1987). However their total absence even at sizes between 70 and 150 mm (1+ cohort) may be a reflection of poor recruitment during the last year or two. The other juvenile classes are represented (Fig. 2) and show that some recruitment of adults will take place over the next several years. However the overall low representation (48%) of juveniles is a point of concern when one considers the heavy natural mortality juvenile conch are susceptible to (Appeldoorn 1988b) added to the fishing mortality seen in shallow areas around the cays of individuals as small as 130 mm in shell length. It is thought that much of the present fishing mortality is due to conch being used as bait in the persistent line fishery allowed within the reserve. Both adult categories are represented in the samples. The normal category are younger adults from six to 12 years old and represent the future bulk of reproductive activity. Finally the stoned category are currently engaged in the most successful breeding activities (Berg *et al.* 1994), represent 25% or more of the total population, and are considered the main brood stock and the future of any short term recovery of the stock. These individuals represent the oldest specimens from 13 to perhaps 26 years old (Coulston *et al.* 1988).

The low overall abundance and density is a reflection of the past heavy exploitation. Former fishermen describe specific shallow seagrass and rubble beds as areas that once supported large populations of juveniles and adults but upon inspection today yield few, but more often no conch. The large extensive areas of deep water (>21 m) AP seem unsuitable for conch in this region at this time although such areas have been seen to be used extensively by all categories especially adult conch in other areas such as Pedro Bank, Jamaica (Tewfik 1996). The shallow (<10 m) SG and RF seem to be the most favorable areas for conch at this time and serve as important nursery and reproductive areas. It is quite apparent that the available habitat could support a much more extensive conch population given the opportunity for recovery.

Observations of reproductive activity (copulation, spawning) and other small adult aggregations at several locations within the reserve seemed to be concentrated on SG slopes that were populated almost exclusively by adult conch. Such breeding aggregations have been identified in other areas (Berg *et al.* 1994). The locations near slopes provide access for mature adults between shallow sandy breeding areas in the warmer months and deeper feeding areas during the rest of the year. Such migrations have been observed by other researchers and seem to be controlled by bottom-water temperature (Weil & Laughlin 1984, Stoner & Sandt 1992). The regularity of these migrations seems to increase with the age of the individual animal as it matures (Hesse 1979) which may further support the idea that these migrations are for reproductive reasons. The confirmation of these reproductive migrations at Cayos Cochinos must be made by monitoring the movement of tagged adults over the entire year.

Although copulation has been observed on occasion by several authors (Randall 1964, D'Asaro 1965, Berg 1975, Hesse 1976, Buckland 1989, Reed 1995) the activity has only been described as the male's verge being extended under the protection of the flared shell lip of both shells and up into the female's vaginal groove. Observations of two pairs of copulating queen conch in Cayos Cochinos add important details to the description. In both cases the male conch were behind and on top of the posterior portion of the females flared shell lip with the muscular foot of the male firmly attached to this area. The verge was, as described in earlier references, extended forward from the male and under the females shell and inserted into the vaginal groove. The attachment by the male to the female shell via the foot seemed to raise the posterior portion of the females shell to perhaps allow ease of extension of the verge under the female's shell lip. The attachment of the foot was so firm that the pairs were picked up as one unit without either pairs separating or the verge of either male retracting. An ex-fishermen, now park ranger, at Cayos Cochinos marine laboratory commented that he was able to sex conch based on the larger size of the posterior part of the shell lip flare in female conch. The observations of copulation may provide reason for this enlarged posterior flare in females in providing a point of attachment for males as well as serving to protect the vulnerable verge during copulation.

Based on the mean shell lengths of the M (185.7 mm) and L (219.1) juvenile categories and an average growth rate of 170 and 150 microns/day (5.1 and 4.5 mm/month), since growth slows with age, respectively the approximate mean ages of the M and L juvenile populations would be three and four years old. Previous studies have often used three juvenile cohorts to describe the juvenile population but it seems reasonable that there are four with perhaps as many as five present: 0+ year, being the in faunal group of less than 70 mm in shell length; 1+ year, the first juveniles to be seen (Sm) from 70 - 150 mm; 2-3 year, M category, 150 - 200 mm; 3-4 year, L category, > 200 mm; and 4-5 year, SA category where the initial shell lip formation begins as shell length growth decreases and finally stops in early adulthood. Fig. 3 shows that perhaps the M and L juveniles are representing a single cohort with SA as the fourth and final one. The limited data available in this study, the partial recruitment of early cohorts, the extensive overlapping of cohorts because of the extensive reproductive season, and the variable recruitment of juveniles into adult cohorts make the understanding of juvenile growth and ultimately aging difficult (Appeldoorn 1987).

The questions and problems in adult growth and aging have also been addressed. Fig. 4 shows the difficulty in using shell length to age in adults. Shell lip thickness frequency may be used to age adults (Appeldoorn 1988a) however Fig. 5 shows that conch of similar ages (e.g. normal adults, 6-12 yrs old) may have lip thickness over a wide range. The subjective categorization based on the morphology of the shell (S= thick, warn lip, warn spines, etc.) is a simple and effective means of separating the adult population into younger (N) and older (S) adults. Comparisons by t-test between lip thickness of N and S category conch show a significant difference ($p<0.0001$). This confirms the effectiveness of the adult categorization using shell morphology. The exact age of adults may not be of importance for questions of fisheries management and broad term censuses such as this study.

It is apparent from the morphometric measurements that shell length and shell width reach their mean maximum (LTH = 241 mm, WTH = 103 mm) upon sexual maturation of the individual between the SA and N categories (Table 2). This corresponds roughly to between four and six years of age. Age of first reproduction has often been estimated at between three and four years of age (Berg 1976, Hesse 1976, Appeldoorn 1988a, Buckland 1989). The addition of one juvenile cohort, described earlier, shifts age of first reproduction one year ahead.

The maximum shell lip thickness and total weight are seen in the stoned category (see Table 2, c,d) which appear heavy lipped buy extremely worn. This reflects shell growth by the mantle from within and bioerosion of the shell by the marine environment on the outside. Although absolute ages are impossible to predict due to varying rates of growth and bioerosion it is not unreasonable to assume ages of 13+ and even in excess of 20 years in very thick lipped, very worn stone conch. Stoner and Sandt (1992) suspect that longevity estimates (5-7 yrs old) by Appeldoorn (1988a) are conservative due to the use of relatively young, uneroded (Normal) adults. The linear regression analysis between the various morphometric measurements (Table 3) reveal that such correlations are best made with juvenile measurements and are seriously flawed when using adult conch (N,S) largely because of the change in shell growth from length to lip as well as the problems of bioerosion.

The proper management of a fishery such as the conch resource in Cayos Cochinos through the use of specific measures or regulations requires that certain information is available on which to base management decisions. This study represents the beginnings of the information needed for such decisions.

The choice of what specific management measures to use are dependent on the state of the stock (healthy vs. over fished), stock location (near shore vs. bank), elements of the harvest sector (artisinal vs. commercial), and the use of the resource (domestic vs. export). Management measures include the use of size restrictions, seasonal and area closures, gear and vessel restrictions, and bulk harvest restrictions (Tewfik 1995). The five year moratorium on all fishing activity, except line fishing, within the reserve is perhaps the strongest action that could have been taken to preserve all marine resources. The state of the conch, lobster, and finfish populations demanded that such action be initiated so that recovery of the resources had a potential hope of success in the near future. It is recommended that no active conch fishery is opened before a subsequent full assessment of the population is undertaken in another two to four years to see if recovery is ongoing from the time when this study was completed. If it is deemed that the conch resource is again available for harvest it should have restrictions attached to it. Harvest should only be free-diving by Garifuna fishermen based in the cays within the reserve. This will ban commercial harvest and limit exploitation to shallow areas. It is also recommended that if a minimum shell length restriction for conch be maintained it be modified from the present 220 mm shell length to a length of 240 mm. This will allow the 45% of L juveniles and 87% of SA that are in excess of 220 mm (Fig. 3) an opportunity to reach maturity. It would be preferable to use a minimum size restriction such as a shell lip thickness of greater than 4 mm which would guarantee that no juveniles be harvested. Finally the closure of important nursery (permanently) and breeding (seasonally) areas could provide refugia for some conch from exploitation. Any rehabilitation programs such as hatchery reared reseeding should only use local genetic stock. Although the present study does provide some important information on this conch stock a more complete investigation is highly recommended.

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RESUMEN

Una evaluación visual de la población de *Strombus gigas* en el área de la Reserva Biólogica de Cayos Cochinos se llevo acabo mediante el buceo de transectos. Datos adicionales sobre el tamaño/ edad de la estructura, morfometrías (largo de concha, ancho de concha, espesor del labio de la concha y peso total), hábitat y la avtividad reproductiva también se recolectaron. La frecuencia de distribución de tallas se da para la longitud y el espesor del labio en un esfuerzo para dar a conocer el crecimiento y edad de los diversos grupos. Se condujeron análisis de regresión lineal entre diversas medidas morfométricas. Un total de 40 transectos se completaron cubriendo un área total de 45 504 m2. El área promedio por transecto era 1 137.6 m2 a una profundidad media de 15.3 m. La densidad total se calculó en 14.6 caracol/hectárea (S.D. = 36.15) sobre el área de estudio de 15 330 hectáreas dando un total de abundancia áproximado de 223 818 caracoles. La mayoría (58.8%) de los caracoles se encontraron en los transectos a menos de 10 metros de profundidad. Un tota de 177 caracoles se recolectaron dentro y fuera de los transectos con 48% juveniles y 52% adultos. Adicionalmente la población se dividió en seis categorías para la evaluación rápida durante los transectos: cuatro juveniles; pequeño (0%), medio (10.7%), grande (19.8%), sub-adulto (17.5%): y dos adultos normales (27.1%), y adultos antiguos (24.9%). La actividad reproductiva incluyó copulación, desove y masas individuales de huevos concentradas en las márgenes de pastos marinos desde 5 a 18 metros de profundidad. Se cree que la baja densidad y abundancia son el resultado directo de los 30 años de explotación severa realizada por los pescadores Garífuna y buzos comerciales con anterioridad a la creación de la Reserva. Las medidas de manejo en el futuro deberán incluir el aumento de la restricción mínima de longitud de las conchas a 240 mm, el uso del grado de madurez (basado en espesor del labio) dentro de las futuras regulaciones. La prohibición de pesca con tanques y clausuras estacionales de las áreas importantes de reproducción.

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