# THE FISHERY FOR ENDEMIC CHITONS IN THE GALAPAGOS ISLANDS

**By: Adelaida Herrera, R. H. Bustamante and S. A. Shepherd**


## SUMMARY

A local or cottage fishery, principally for the endemic chiton *Chiton goodalli,* persists in the Galápagos Islands despite declining numbers of chitons. Restaurant consumption has also declined in recent years. The size structure of animals in past and recent catches was estimated from examination of shell middens on the coast near Puerto Ayora, Santa Cruz Island. The number of chitons sold annually in restaurants was estimated from questionnaire responses received from restaurant owners in Puerto Ayora. Sampling at study sites from 1996-2000 showed that densities of chitons on exposed coasts have declined, consistent with overfishing of localized populations. Recruitment to a size that can be conveniently sampled was variable between sites and between years, but occurred mainly between March and November. We propose a legal minimum harvest size to encourage conservation of local populations and to prevent growth overfishing (excessive fishing that removes all adults locally).


## INTRODUCTION

Chitons, or coat-of-mail shells, are a group of mollusks having eight interlocking plates dorsally as protection instead of the one or two shells that most other mollusks have. Like gastropods, they use the muscular foot for adhesion to the rock surface to which they are attached.

Coastal inhabitants have traditionally eaten chitons found in the intertidal zones. Aborigines in the western Kimberleys of northwest Australia harvest *Acanthopleura spinosa*. Native Alaskans take *Katharina tunicata*. Indians of Puget Sound favor *Cryptochiton stelleri,* and islanders in the Bermudas and Lesser Antilles have harvested chitons as well (Beesley *et al.* 1998).

In the Galápagos Islands, chitons, locally known as "canchalaguas", have been a popular food item and harvested since the earliest days of human habitation (Ferreira and Ferreira 1977). Most recently, the fishery has existed mainly on the inhabited islands of Santa Cruz, San Cristóbal,Floreana and Isabela, but harvest is known to occur to a lesser extent on the uninhabited islands of Gardner por Española, Santiago and Genovesa, and has probably occurred on others in the central and southern parts of the archipelago.

Chitons are typically cryptic by day, hiding in narrow crevices in the rocky intertidal zone, but emerge at night to graze on micro-algae. Thus, fishers walking in this zone, preferably during a full moon, can prise the chitons from the rocks with a knife or other sharp object. Once harvested, the chitons are processed by excising the foot and gonads and discarding the shells and viscera in middens on the upper shore.

In recent years, this fishery has grown from a traditional subsistence level to a small-scale commercial activity. Local markets in Santa Cruz and San Cristóbal sell chitons, and restaurants offer chiton as a typical "ceviche de canchalagua" (raw, chopped seafood marinated with lemon and spices) on their menus.

Thirteen species of chitons are recorded intertidally in the Galápagos Islands (Finet 1994), and six of them are endemic. Two of these endemic species, *Chiton goodalli* (Broderip 1832) and *Chiton sulcatus* (Wood 1815) grow to a large size (80-150 mm total length) and are abundant compared with the other species. While both species are found in the archipelago (Bullock 1988) , *C. goodalli* is much more abundant on exposed coasts where most harvesting occurs.

The only previous studies on these chitons are by Salguero and Carvajal (1989) and Tirado (1996), but neither considers the reproductive biology, ecology or population biology of the species. As there are clear signs of local depletion of chiton populations, there is a need for basic biological information about the species in order to manage the fishery and conserve the species.

This paper describes the size structure, density and recruitment patterns of lightly and heavily fished populations of *C. goodalli* on the southern coast of Santa Cruz Island. Shell collections from middens yielded information on the size structure of animals in past catches. The magnitude of the commercial catch in recent years was estimated from questionnaire responses by local restaurateurs in the town of Puerto Ayora, Santa Cruz (Fig. 1).

## METHODS

Samples of 20 - 30 *C. goodalli* were taken monthly from Punta Estrada and/or Barranco, with infrequent samples from Academy Bay, Punta Núñez and the Caamaño Islet, from 1995- 2000 (Fig. 1). Following a standardized sampling protocol at selected sites, we searched systematically under boulders and in crevices for *C. goodalli* for one hour per visit and measured the shell length (SL) of every accessible chiton to the nearest 0.1mm. Morphometric data on shell length (SL), total weight, foot weight, gonad weight, sex, species, and length and width of the cephalic plate were obtained from a sub-sample. By least squares regression analysis, equations were derived expressing the relationship between various morphometric mea-

sures of interest. Individuals <20 mm SL were rarely found, so the size class 20-50 mm SL was used as an index of recruitment of *C. goodalli* to the population.

Fixed quadrats were placed in the low- to mid-intertidal zone at four sites between the dock of the Charles Darwin Research Station (CDRS) in Academy Bay (AB 0, 1, and 2) and Punta Núñez (Fig. 1). At each site 6-8 permanent quadrats of 1m² were demarcated with patches (each 1 cm²) of white epoxy glue fixed to the rock at the corners of each quadrat.

Once or twice monthly, the sites were monitored for the presence of chitons during a low tide. Shell length of accessible animals was recorded as well as habitat characteristics, including wave swell, rock type, and other intertidal sedentary fauna present. At all sites except Punta Nuñez, the substratum is of large heterogeneous blocks of black volcanic "aa" lava. At Punta Núñez the substratum is predominantly sand, "pahoehoe" rope lava, and small boulders 5-30 cm diameter (Walsh 1993).

The mid-intertidal is typically carpeted with a green algal mat of *Ulva lobata* on horizontal surfaces and a *Gelidium* sp. turf on vertical surfaces. Common mollusks indicative of mid-tidal levels include: *Purpura pansa*, *P. columellaris*, *Hoffmannola lesliei*, *Acanthochina hirudiniformis* and the barnacle *Tetraclita stalactifera*. Other common fauna include the sally lightfoot crab *Grapsus grapsus*, the small anemone *Isoactinia* sp. and the herbivorous marine iguana *Amblyrhynchus cristatus*.

Field surveys of chiton shell middens left by fishers were carried out along the southern coast of Santa Cruz Island from August 1994 to August 1999. In each midden, shell fragments were collected and the width of all cephalic plates of *C. goodalli* was measured to the nearest 0.1mm. From the relationship between cephalic width and total length, the distribution of shell lengths of chitons taken by fishers was predicted from the cephalic plate measurements. The midden sites were revisited during the period of the study to determine the extent of subsequent fishing. Shells of chitons killed between visits retained their dried integument and were easily distinguishable from older, weathered shells.

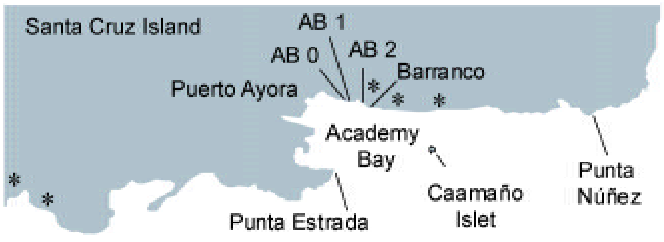


**Figure 1.** Map showing sites on the coast of Santa Cruz Island near Puerto Ayora where chitons (*Chiton goodalli* or *Chiton sulcatus*) are taken by fishers. The five sampling sites named in the text are: Academy Bay (AB 0, 1, and 2), Barranco, Caamaño Islet, Punta Nuñez, and Punta Estrada. Fixed quadrats were monitored from 1994-1999. Asterisks (*) indicate the presence of shell middens.

In order to estimate the size of the commercial fishery for chitons, a questionnaire was prepared and distributed to local restaurateurs in 1995 and again in 2000.

## RESULTS

*Chiton goodalli* and *C. sulcatus* have been recorded from all the larger islands (Santa Cruz, San Cristóbal, Isabela, Fernandina and Floreana) and a few smaller islands of the archipelago (Santiago, Española and Santa Fé). The habitat of *C. goodalli* is deep within narrow crevices formed by large boulders and blocks of lava in the mid-to-low intertidal where rocks are exposed to strong wave action.

### *Morphometrics*

A total of 1391 *C. goodalli* were taken intertidally from Santa Cruz.

The relationship between total weight (TW g) and shell length (SL mm) is given by the equation:

$$TW = 7E - 0.5\ SL^{2.948} \quad (R^2=0.88,\ N = 1372)$$

The relationship between the width of the cephalic plate (C) and SL is given by the equation:

$$SL = 4.94 + 2.585\ C \quad (R^2=0.94)\ (N= 144)$$

### *Densities, Size Structure and Recruitment*

Densities of *C. goodalli* in the fixed quadrats in Academy Bay declined significantly from 1994 to 1999 at four sites (2- tailed Kolmogorov-Smirnov, P= 0.082), but increased slightly at the eastern end of Academy Bay during the same period (Fig. 2). Length frequency distributions for all samples combined from Santa Cruz and for all midden shells derived from cephalic plate measurements (Fig. 3) show that while fishers obviously selected for

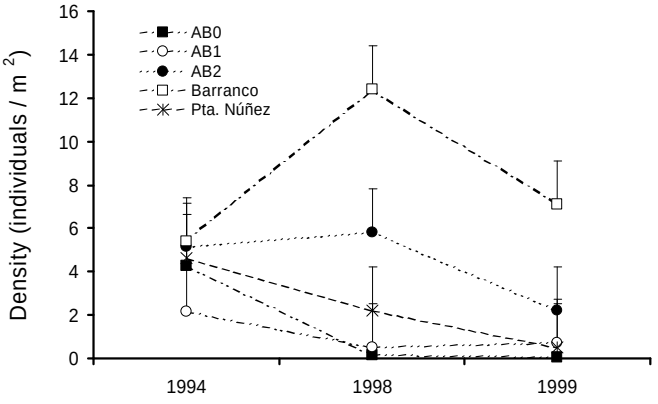


**Figure 2.** Change in density of *Chiton goodalli* over time at four fixed sites in Academy Bay and one at Punta Núñez, Santa Cruz. Vertical bars are plus one standard error.

larger shells, they still took substantial numbers of shells < 85 mm SL. The modal size of midden shells (100.0 mm SL; s.e 16.8 mm) is significantly larger than that for the wild population (80.0 mm SL; s.e. 24.7 mm) ($X^2$= 366.563, df = 1, P<0.05). Similarly, the maximum size of midden shells was 165 mm, compared with 145 mm for the wild population. At Caamaño Islet, which is seldom visited by fishers, the modal size of shells (110.5 mm) is significantly greater than on Santa Cruz (82.20 mm) ($X^2$=28.855, df = 1, P<0.05).

Recruitment strength, as estimated from the numbers of individuals in the 20-50 mm size class, varied between and within years (Fig. 4). At Punta Estrada, recruitment was recorded mainly from February to July and was high in 1996, 1999 and 2000, whereas at Barranco, recruitment was highest variously from March to November in 1997 and 1998.

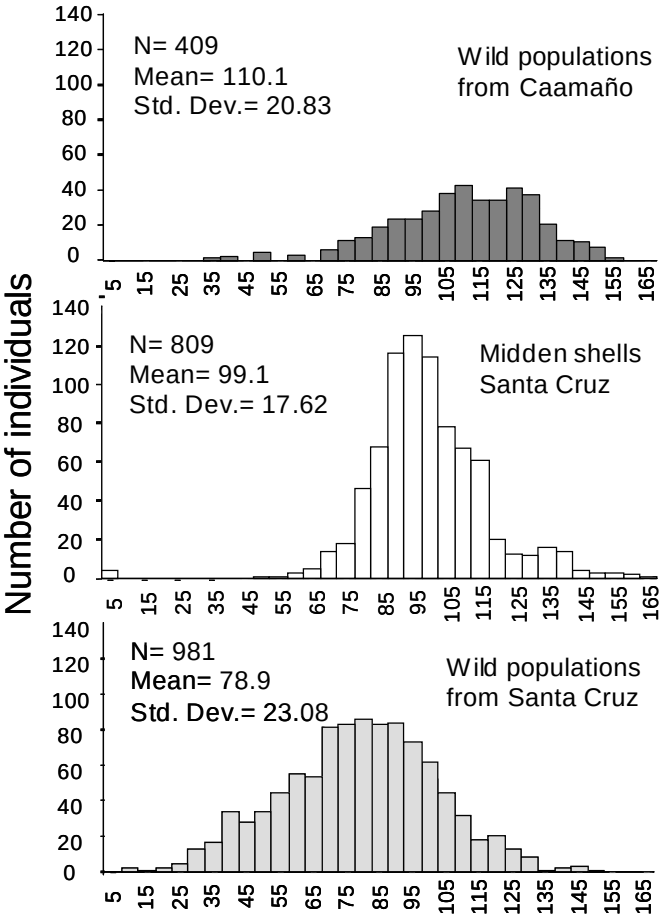


**Figure 3.** Length frequency distributions of shell lengths (SL) of *Chiton goodalli* in wild populations from Caamaño (top), from midden shells on Santa Cruz (middle) and from wild populations on Santa Cruz (bottom). Data for wild populations were obtained by researchers' direct sampling; data for middens were estimated with morphometric equations applied to shells and shell fragments left by fishers.

### *Chiton Harvests*

Between Academy Bay and Punta Núñez, nine middens with 4,146 shells (cephalic plates) were found from August 1994–98. At Punta Núñez alone, the middens were conservatively estimated to contain about 2,200 shells.

Seven restaurateurs completed the questionnaire in March 1995. The total amount of chiton meat then purchased by the 10 restaurants was about 22 kg (meat weight) per month. Assuming that the midden data reflected the sizes of chitons sold to restaurants, we calculated that about 1,100 chitons were sold per month to restaurants, in addition to those taken for home consumption.

A subsequent questionnaire administered to 30 hoteliers and restaurateurs in January 2000 in Puerto Ayora indicated that consumption in hotels was negligible and very low in restaurants, equivalent to only about 130 chitons per month. Data from these surveys showed that local residents (63%) consumed more chitons than national visitors (36.36%) or foreign visitors (0%).

Fishers customarily collected from the intertidal zone and sold their catches once or twice per month. The catch was mainly chitons but also included some sally lightfoot crabs, *Grapsus grapsus*, and gastropods in the genera *Nerita* and *Purpura.*

## DISCUSSION

This is the first general report on the chiton fishery in the Galápagos, but interpretation of the data is still hampered by lack of information on the biology of the species. Ongoing studies by the first author (unpublished data) show that the spawning cycle of *C. goodalli* is year round although spawning peaks may occur in March and October. The average size at onset of sexual maturity is about 90 mm. The data show that recruitment to the population at two sites is irregular over time and not obviously related to the El Niño phenomenon.

The data suggest that the intensity of chiton harvest declines with increasing distance from Puerto Ayora. Since 1995, densities of *C. goodalli* have declined more conspicuously closest to Puerto Ayora. The ready accessibility of Pta. Núñez by boat explains the high intensity of fishing there. Mean sizes of chitons on the offshore island of Caamaño are probably larger due to the low fishing pressure. The decline in chiton densities can almost certainly be attributed to human harvesting rather than the natural mortality or recruitment failures by considering both the midden evidence and the estimated aggregate human consumption of chitons.

Many parts of the coast of Santa Cruz such as the cliffs at El Barranco are difficult to access by local chiton fishers, and so may have virtually pristine densities of *C. goodalli*. Unless recruitment is largely restricted to very localized parental stocks, it is difficult to believe that even intense

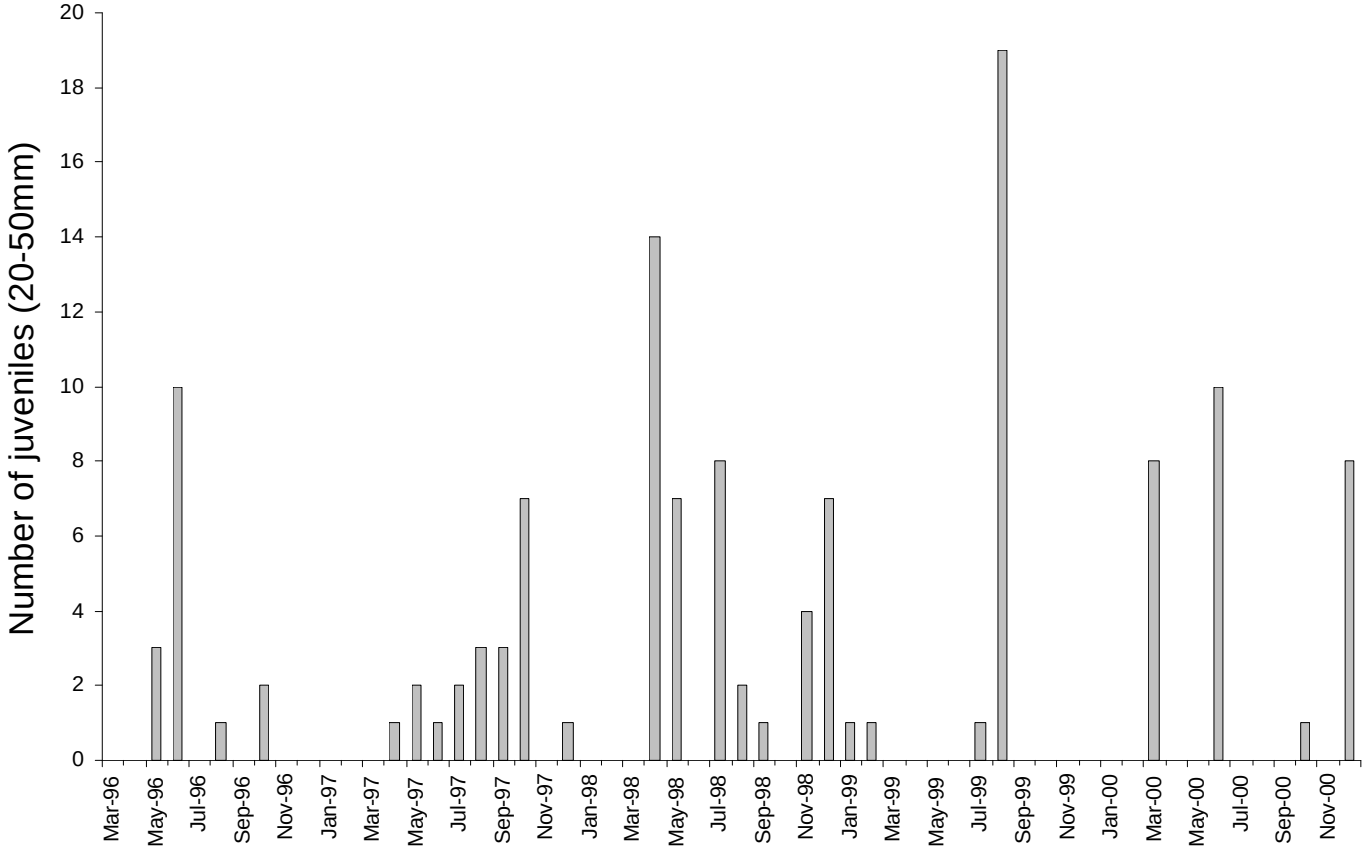


**Figure 4.** Recruitment in numbers of juveniles (20-50mm SL) of *Chiton goodalli* per hour searching time at Punta Estrada and El Barranco during monthly sampling from 1996 to 2000.

local harvesting will seriously affect recruitment to local populations. Hence, although growth overfishing (excessive fishing that removes all adults locally) may well have occurred on parts of the coast of Santa Cruz near Puerto Ayora as indicated by the substantial numbers of sexually immature chitons caught, recruitment overfishing (overfishing of spawning stock that causes recruitment failure) has not been established. Very small *C. goodalli* of about 1mm SL have been observed in the intertidal *Gelidium* and *Ulva* mats in Academy Bay, and it is possible that this is the habitat in which the larval settlement of this chiton occurs. Questions of recruitment variability and stock-recruitment relationships may best be examined by the use of artificial collectors placed in the intertidal zone.

It is clear from the midden data that many chitons are harvested at a suboptimal size. We recommend that a minimum size of capture be imposed in this fishery. The appropriate minimum size limit should be determined after taking into account size of sexual maturity and intensity of harvesting. This would eliminate the problem of growth overfishing and would encourage fishers to conserve stocks.

The estimated 88% decline in consumption of chitons in restaurants and hotels between 1995 and 2000 is consistent with the local depletion of chitons in Academy Bay. However, from the number of chitons still found in local middens, it is likely that many more chitons are taken for domestic consumption than are accounted for by sales in restaurants in Puerto Ayora. As yet, the total catch of chitons is still speculative.

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# PHENOTYPIC VARIATION IN *CALANDRINIA GALAPAGOSA* (PORTULACACEAE)

## By: Patricia Jaramillo


### ABSTRACT

*Calandrinia galapagosa* St. John is found only on San Cristóbal Island in the Galápagos archipelago, where it is severely threatened by feral goats. A population at Cerro Colorado is protected by an exclosure constructed for this purpose in 1993. Individuals of this population have white or pinkish white flowers with a green stem, whereas the population at La Galapaguera, has pinkish white flowers with a purple stem.


### INTRODUCTION

There are 60 species of the genus *Calandrinia* (family Portulacaceae) in Australia and 40 species in the Americas. Some are cultivated as ornamental plants because of their fleshy leaves and attractive flowers. Polymorphic species are found in the subgenera *Baitaria, Cistanthe*, and *Rumicastrum* (Mabberley 1997). In Galápagos, Stewart (1911) reported a *Calandrinia* for the first time from Sappho Cove, on the central north coast of San Cristóbal Island.

Later, St. John (1937) noted differences between Stewart's collection and other species of *Calandrinia*, specifically *C. splendens* from Chile. He established that the sepals, the number of stamens, and the seeds were different, and he described it as a new species, *C. galapagosa*, endemic to Galápagos. Later, Eliasson (1968) reported 20 bushes, which were non-reproductive and severely grazed by feral goats, surviving only on inaccessible cliffs. In 1977, H. Adsersen (pers. comm.) found some plants on lava at Bahía Rosa Blanca (non-reproductive specimens, Charles Darwin Research Station Herbarium).

In 1993, Jacinto Gordillo (pers. comm.) reported a population on Cerro Colorado at an altitude of 150 m on a red clay soil. Ortiz (1994) noted the danger of extinction of this species, mainly due to pressure by feral goats. This site was therefore protected by a 300 m barbed wire fence built in 1993. This fence was never entirely adequate and deteriorated over the years, permitting access by goats once more. It was therefore replaced by a chain-link fence built in 1999 by the Charles Darwin Research Station and Galápagos National Park Service. This exclosure protects not only the largest *Calandrinia* population, but also a large population of the threatened San Cristóbal endemic *Lecocarpus darwinii.*

Arsiniegas (1996) reported a new *Calandrinia* population in four small cones to the southwest of the cone "Media Luna" and in two larger cones located southeast of the cones "Calzoncillo" and "Pan de Azúcar" in the eastern part of the island in the section called La Galapaguera. These individuals are protected from the donkeys and feral goats that exist in the area due to their location on the vertical walls of the cones. In 1999, Alan Tye and Patricia Jaramillo (pers. obs.) found three individuals of this species at a new location at Bahía Rosa Blanca.

In this study I report differences in the color of the leaves and flowers between individuals found at Cerro Colorado and La Galapaguera.