Stock Assessment of "Chame" *Dormitator latifrons* in Nayarit and South of Sinaloa México

Indigenous Species Development /Study/09IND04UH

Guillermo Rodriguez Domínguez
Universidad Autónoma de Sinaloa – Mazatlán
Mazatlán, Sinaloa, Mexico

Maria Haws
University of Hawai'i at Hilo
Hilo, Hawai'i, USA

Students:
Jesus Sanchez Palacios, Gloria Ana María Arroyo Bustos and Josefina Ruiz Moreno
Universidad Autónoma de Sinaloa – Mazatlán
Mazatlán, Sinaloa, Mexico

INTRODUCTION

"Chame" is a common euryhaline fish of Mexico, and much of the Pacific Coast of Latin America. It survives in a large range of temperatures and salinities in lentic and lotic environments. It is used for food in southern Mexico, but is considered a pest in northwest Mexico because it invades commercial shrimp ponds where it competes for feed. This fish has a vascularised swim bladder that can function as a primitive lung (facultative lung) and thus can survive a long time out of water. Because of its resiliency to extreme environmental conditions it will be important species if global warming is a reality. Its cultivation for human food may be an alternative when other species are impacted by global climate change.

Relatively little is known about this species' biology. A reproductive autumn season was reported (Navarro Rodríguez et al, 2004; Navarro Rodríguez et al, 2010; Rojas Herrera et al. 2009) but a reproductive winter season was also reported (Florencio y Serrano, 1981). Another study found two reproductive seasons a year (Navarro Rodríguez et al., 2006). Isometric growth (Rojas Herrera et al. 2009) and growth of 24 g in two and half months of cultivation was reported (Castro Rivera et al. 2005). A female of 155 mm length can produce five millions eggs (Haz Alvarado 2002). It spawns in estuaries where mass eggs adhere to the roots of the mangroves and then the 20 mm larvae migrate upstream (Haz Alvarado, 2002).

The principle objective of this study is to collect information about this species' basic biology and conduct a stock assessment in two Mexican States where this species is fished and has potential as an aquaculture species. This information will support development of fisheries management recommendations and provide information to aquaculture development efforts.

MATERIAL AND METHODS

Survey catches of "chame" were conducted using cast nets with 1 inch mesh size in rivers, streams, coastal lagoons estuaries and marshes of southern Sinaloa and northern Nayarit Mexico (Figure 1). In each survey site 10 catch sets were realized and the number of fish caught recorded. Sex, total length, total weight, and gonad weight were also recorded. Scales and gonads were collected from five fishes from each 10 mm size class.

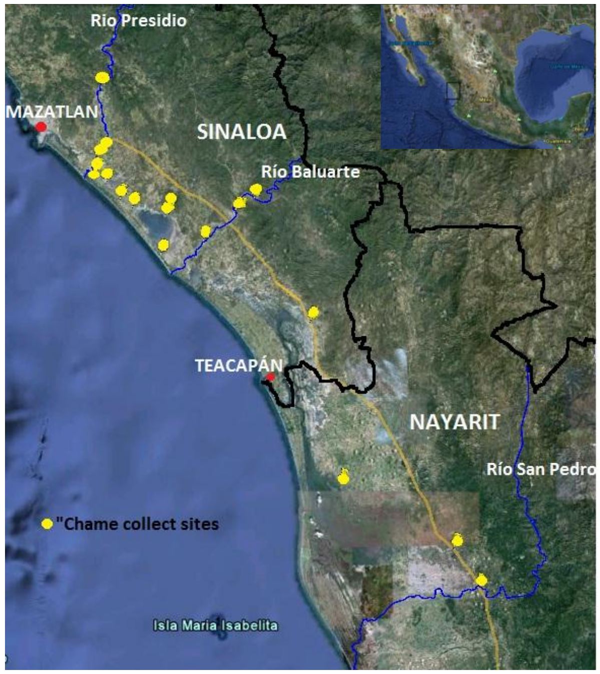

Figure 1. Study area and collection sites of "Chame" in southern Sinaloa and northern Nayarit.

Cleaned scales were air-dried, mounted on microscopic slides and examined with a Bausch and Lomb overhead projector. Six of the best scales were selected for further analysis. For each fish scale, total and partial radius were measured using a projection scale at a constant distance and microscopic objective for two independent observers To determine if scales could be used for estimation of growth, the total radius of the scale was regressed to the total length of fish and statistical significance was determined using analysis of variance. Lengths and weights of fishes were grouped for the number of growth marks and fitted to a normal distribution, and the parameters μ and σ were estimated for each one. The periodicity of growth marks was evaluated by examining mean marginal increments of the scales. To validate the timing of mark formation, monthly mean Fulton's condition factor ($\overline{K}$) and the gonadosomatic index were estimated.

Data for size at age were fitted to four cases of Schnute's (1981) model and one special case equivalent to the von Bertalanfy model. Each case was fitted to the size at age and weight at age data set by the maximum log-likelihood algorithm of normal distribution of errors, assuming both additive and multiplicative error structure. The best fit of error structure and of each case for the Schnute model was determined by the Akaike index (*AIC*) and the Akaike weights (W_i) (Montgomery et el 2010).

The relationship between weight (Wt) and length (Lt) of fishes was estimated by a potential model. The model was developed using non-lineal methods maximumizing a Log-likelihood function by a iterative process with Newton algorithm. Models were bootstrapped 1000 times to estimate first-order corrected 95% confidence intervals about each parameter (Haddon 2001).

Maturation stage were determined macroscopically in the laboratory using freshly captured specimens,. Samples of gonads were also taken and placed in Davidson´s fluid for subsequent histological analysis. Macroscopic maturation stages were: Stage 1. immature and sex undifferentiated; Stage 2. gonads developing; Stage 3. gonads maturating; Stage 4. mature; and Stage 5. spawing. Stages 3 to 5 were considerate to be mature fishes during reproduction season. Fishes collected in the reproduction season were sorted as immature and mature for each 5 mm of total length interval and adjusted to the logistic model to estimate size at first maturity.

Fish caught at all survey sites and for all months were standardized as catch per 10 sets and pooled in 10 mm of total length interval. Then frequency in each age group (Na) was calculated by a multinomial approximation (Montgomery et al., 2010) where initial parameter estimates were that of normal distribution fit at each age group as determined by the growth marks in scales. Multinomial fit was obtained by fixing mean length at each age group by the change in standard deviation and frequency (Na). Then Na was used to construct a plot of catch at age curve, and the points in the descendent part of curve were selected for regression and estimation of total mortality rate, as $Ln(Na) = a + Z\bar{t}$

Mortality rate (M) was calculated with four empiric model as:

Reference	Model	Parameters definition and units
Rickhter and Efanov (1976)	$M = \frac{1.521}{t_{50\%}^{0.72}} - 0.155$	$t_{50\%}$ = First age maturity.
Rickhter and Efanov (1976)	$Log_{10}M = -0.0066 - 0.27Log_{10}L\infty + 0.6543Log_{10}K + 0.4634Log_{10}T$	L∞ = asymptotic length (in cm) K = growth coefficient (year^{-1}) T = annual mean temperature of habitat. (◦C)
Hewitt and Hoenig (2005)	1.5 (3/a_{max})	a_{max} = Maximum age registered.
Cubillos (2003) after Alverson & Carney (1975)	$M = \frac{3K(1-w)}{w}$	w = 0.62 = critic size-asymptotic length ration. K = (growth coefficient (year^{-1}) from vonBertalanfy model.

RESULTS

Chame were caught in ten of the eighteen sites explored. *D. latifrons* was collected all year in freshwater ponds or seasonal freshwater lagoons, and in rivers, streams and estuaries during rainy season from August to November. The catch per set was highly variable depending on the local situation and seasonal conditions. In a seasonal freshwater called Mataderos, catch per set (19.63 m^2 cast net area) was 5 to 10 fishes from March to May (Figure 2). The lagoon dried up in June, but it was filled in a flood in August, and after new chame recruits entered the lagoon, catches per set were 2.6 to 8.5 fishes. In a pond constructed for a source of water for cattle (named Zacatoza), which had been filled continuously with well water, catch per set was 0.05 to 1.8 fishes from March to August. In late August the surrounding fields were flooded and the reservoir turned dark brown and dead fish were observed on the surface. In October, new recruits of chame were observed, and catch per set was from 1.8 to 44.5 fish, from October to December. In a stream next to Potrerillos ranch, many chame were observing attempting to migrate upstream but a bridge over the stream presented this. Some fishes were seen attempting to jump over the wall but were returning with water flow. Catch per set was of 28.3 fishes. In early December, the flow of water was reduced and there only remained a small lagoon next to the bridge where catch per set was of 128 fishes.

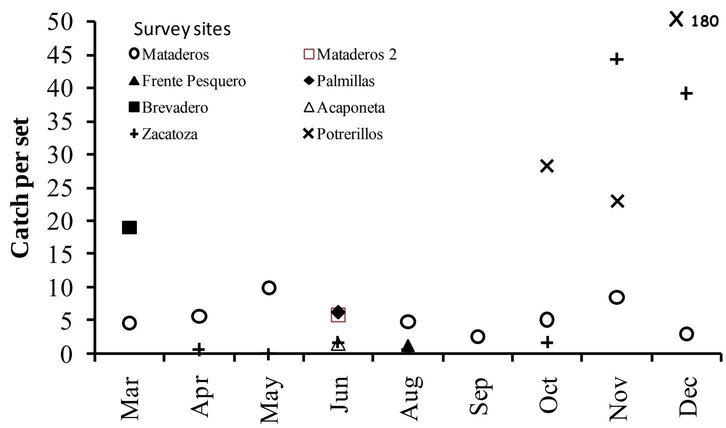

Figure 2. Catch per set of chame (*D. latifrons*) with a cast net in survey sites in southern Sinaloa and northern Nayarit, México.

The observed migration is thought to have been for reproduction because in October 75% of female fishes were mature (stage 4) and for November 87.5% had spawned. In September, chame were captured next to the dam diversion "Tamarindo" on the Baluarte River; 67% were mature. Some smaller fish were observed hiding beneath rocks at this site. Catch per set was not calculated because the rocks prevented the use of cast nets, but 86 chame fishes were captured in 30 minutes for two fishers.

The size of chame captured varied from 56 to 300 mm of total length, but most (79%) were in the 70 to 130 mm interval (Figure 3). A decrease of frequency with size was observed. The weight of the chame varied from 1.5 g to 419 g but most (76.8%) were 40 g (Figure 3).

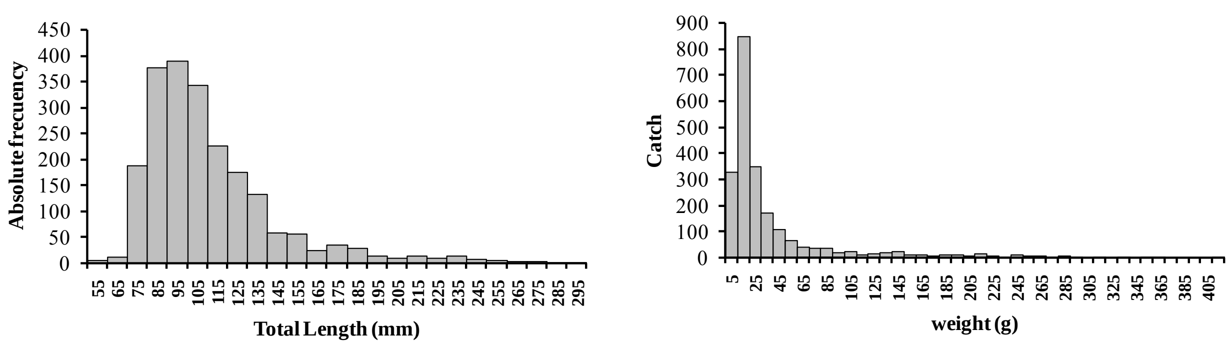

Figure 3. Size and weight structure of *D. latifrons* as sum of standardized catch to 10 set of all survey sites.

The relationship between total length and scale size was statistically significant ($p< 0.05$) with a coefficient of determination of 0.92. This lends validity to the use of scales for age determination. Six growth marks were found on the scales (Figure 4) and the total length of fishes within each growth mark was adjusted to a normal distribution.

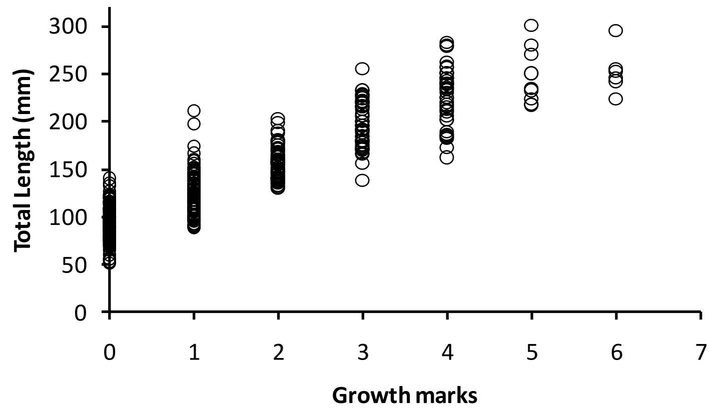

Figure 4. Relation between total length and growth marks in scales of *D. latifrons*.

The mean of the marginal increments described an annual cycle with the lowest means in December and February. (Figure 5). This find validates the hypothesis that growth marks are imprinted once a year from December to February.

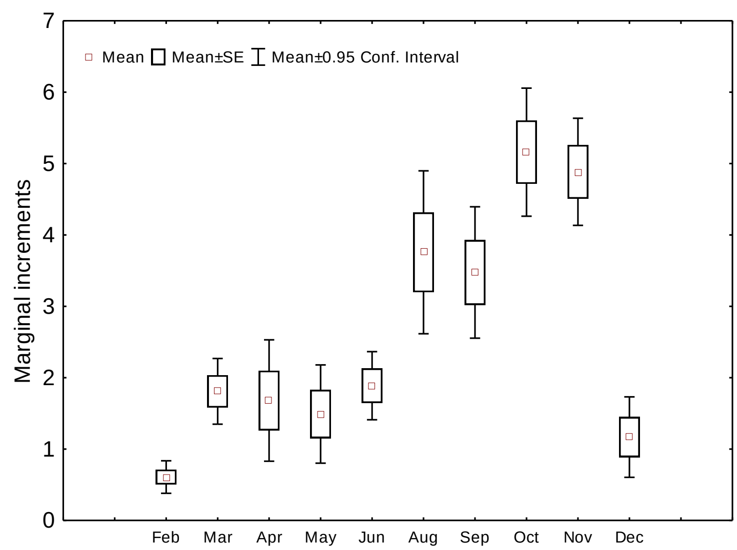

Figure 5. Temporal variation of mean marginal increments of scales of *D. latifrons*. Fishes of all groups of growth marks were included.

Total length and weight for the age groups were as:

age group	Mean total length (CI 95%)	weigth (CI 95%)
0	91(88,94)	13(15,17)
1	120(116,124)	29(33,38)
2	155(151,159)	53(59,65)
3	195(189,202)	123(136,150)
4	227(217,236)	187(213,240)
5	246(230,263)	228(285,341)
6	254(237,272)	187(279,371)

The best fit of growth of size at age was case 1 with additive error structure as was determined for the lower AIK (Table 1).

Table 1. Akaike index after fitting for Schnute model cases and error structure types to size-age data.

ERROR TYPE	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
ADITIVE	34.50	55.39	61.37	66.32	59.17
MULTIPLICATIVE	59.36	62.01	66.37	70.21	64.77

Aikake weight for case 1 has additive error structure being almost 100% as is shown in Tables 2 and 3.

Table 2. Parameters of each case of the Schnute model with bootstrapped confident interval 95% for the best model as determined by Aikake weight.

CASE	y1	y2	a	b	AIK	W_i
1	91.2 (90.48, 91.58)	254.38 (253.71, 254.79)	1.15 (1.08, 1.2)	-4.08 (-4.46, -3.86)	34.50	99.99 *
2	86.31	259.81	0.34	0.00	55.39	0.0
3	87.01	264.17	0.00	1.68	61.37	0.0
4	113.13	276.45	0.00	0.00	66.32	0.0
5	85.83	261.58	0.14	1.00	59.17	0.0

Table 3. Akaike index after fitting five cases of the Schnute model and two types of error structure to weght-age data.

ERROR TYPE	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
ADITIVE	74.05	70.43	81.83	80.48	84.37
MULTIPLICATI	74.10	78.90	82.46	85.70	84.26

The best fit of growth to weight at age was case 2 with additive error structure as was determined for the lower AIC (Table 3) and Aikake weight was 85.16% (Table 4).

The length-weight relation was: $Wt = 0.0000143Lt^{3.019}$. Bootstrapped confident intervals at 95% were 1.18E-5 – 1.62E-5 for parameter *a* and 2.984 – 3.051 for parameter *b*. Confident interval at 95% of *b* include 3 which indicates isometric growth of *D. latifrons*.

Table 4. Parameters of each case of the Schnute model with bootstrapped confident interval 95% for the best model as determined by Aikake weight

CASE	y1	y2	a	b	AIK	W_i
1	15.86	285.34	2.22	-3.15	74.05	13.92
2	1.07 (1, 5.63)	294.45 (279.43, 314.05)	0.64 (0.4, 0.68)	0.00	70.43	85.16 *
3	2.00	294.45	0.00	1.18	81.83	0.28
5	1.97	371.64	-0.19	1.00	84.37	0.08

The condition factor of chame fishes showed an annual cycle according to gonadosomatic index and marginal increments in scales. The lowest values were in March with a maximumum in October, followed by a decreasing trend until December (Figure 6).

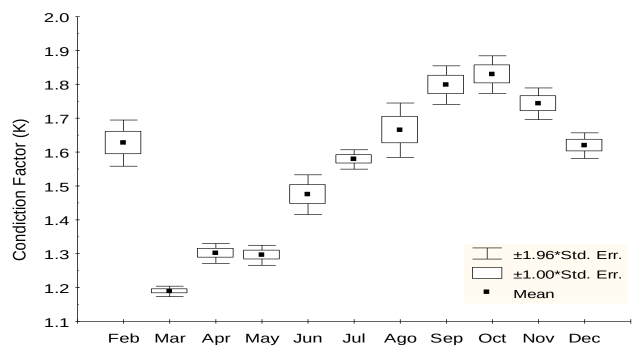

Figure 6. Temporal variation of condition factor for Chame *D. latifrons*.

Macroscopic analysis of the maturity stage of female Chame showed an annual maturation cycle. From March to June, females were inmature or developing. From August to November, most fish were mature. Stage 5 or the spawned stage were seen from November to February (Figure 7).

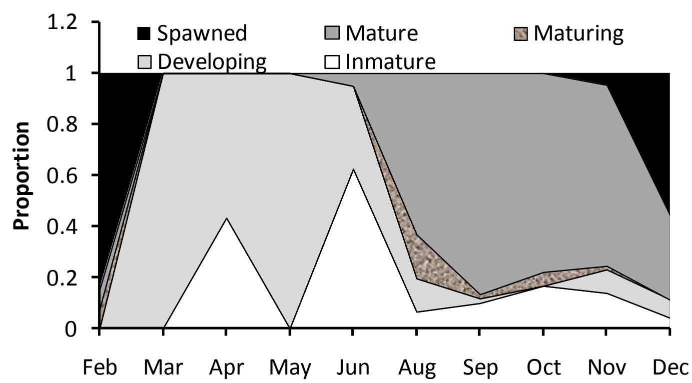

Figure 7. Proportional macroscopic maturing stages of *D. latifrons* over the annual cycle.

Temporal variation of mean GI also revealed an annual maturity cycle (Figure 8). From February to July, GI was low, ranging between 0.5 and 2. Beginning in August, GI began to increase (from 4 to 14) until reaching a maximumum in October, followed by a decline until December. Both the macroscopic maturity stages and GI suggest that the spawning season for chame is from October to February.

Female chame with zero growth marks also showed gonadic maturation as revealed by the gonadosomatic index. This find revealed that *D. latifrons* reach first maturity before they reach one year of age, because the growth mark is impressed in December and these fishes would have been maturating since August. There was only one female with zero growth marks in December that was in spawned condition and one more was found in November. A weighted mean age (frequency times age) revealed that females with zero growth marks collected during this study were 0.845

years old. Mean size of mature females with zero growth marks was 98 mm total length, and those that were immature were 86 mm.

Eggs in gonads of *D. latifrons* are homogeneous in size when are seen in fresh under the microscope and histological analysis of gonads revealed eggs in the same development stage (Figure 9), which validates the hypothesis that *D. latifrons* is a complete spawner.

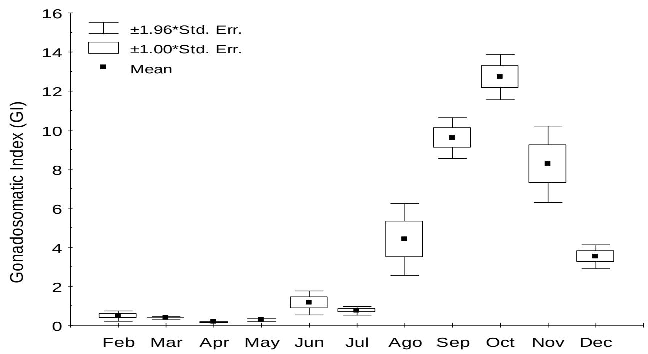

Figure 8. Annual cycle for gonadosomatic index of *D. latifrons*.

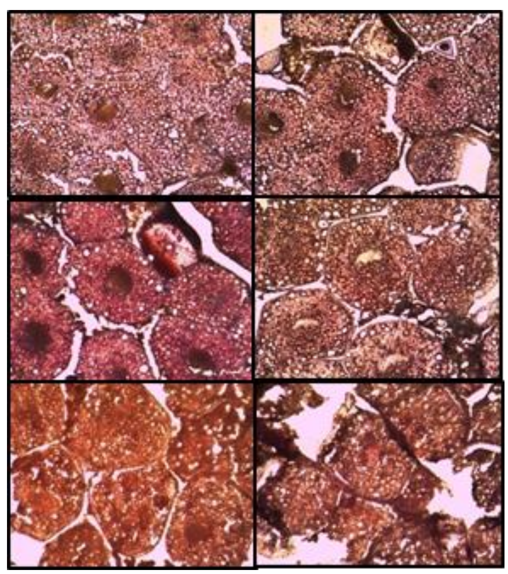

Figure 9. Histological view of mature gonads of *D. latifrons* female of 119 mm (top), female of 115 mm (middle) and female of 90 mm (bottom).

Size at first maturity of *D. latifrons* was calculated at 88.1 mm total length. This size is between immature and maturing females with zero growth marks in scales. As the Schnute growth model uses relative age rather than absolute age to determined age at first maturity, we used a derivation of the best case 1 of the Schnute growth in size model with τ_1 in 0.845 (age of females with zero growth mark in scales) and τ_2 6.845. Age was calculated by substituting Yt for total length at first maturity using the equation below:

$$t = \tau_1 - \frac{1}{a} Ln\left[1 - \frac{\left(Y_t^{\,b} - Y_1^{\,b}\right)\left(1 - e^{-a(\tau_2 - \tau_1)}\right)}{Y_2^{\,b} - Y_1^{\,b}}\right]$$

Age at first maturity was thus calculated to be 0.72 years.

Female chame have a high fecundity. Mature females smaller than 200 mm of total length produced between 39,000 and 170,000 eggs, and females larger than 200 mm produced between 1 and 5 million of eggs (Figure 10). A tendency to to increase the number of eggs per gram of female weight with size was observed, but was not statistically significant (P= 0.09). The mean reproductive potential of chame is 11,910 eggs per g of female weight with a confident interval at 95% of 149,094 and 14,727 eggs.

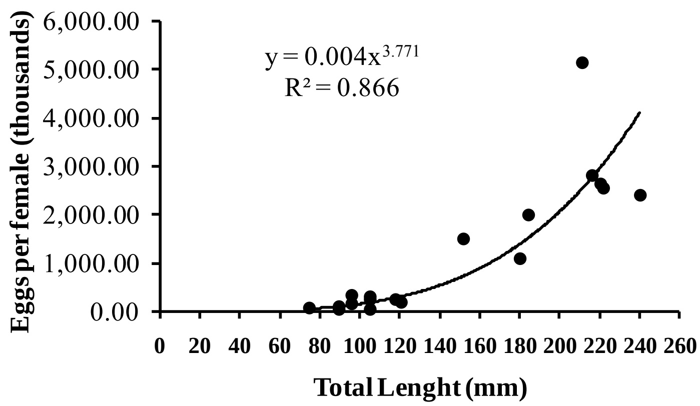

Figure 10. Fecundity for size of female *D. latifrons*.

The catch at age curve showed a decreasing section only, but extreme points no were used to analysis (Figure 11). Mortality rate was estimated at 1.4 year^{-1}.

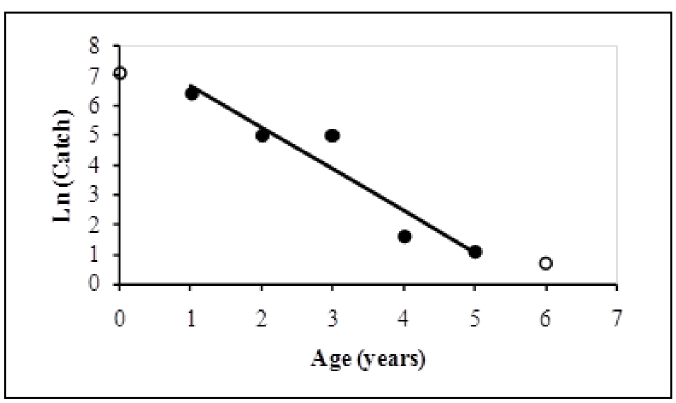

Figure 11. Catch at age curve.

Estimations of natural mortality were derived using four empirical models:

Model	Mortality rate
Rickhter and Efanov (1976)	M= 1.77
Pauly (1980)	M= 0.47
Hewitt and Hoenig (2005)	M = 0.75
Cubillos (2003) after Alverson & Carney (1975)	M = 0.27

DISCUSSION

In most of Mexico this species is not considered a target fisheries species, but is used as bait for fishing and is captured as bycatch in the artisanal shrimp fishery. In the freshwater survey sites, chame was observed to cohabit these areas with other non-predatory species such as tilapia and gobids. In estuaries and costal lagoons, it is subject to predation by catfishes and other species.

Age at first maturity was calculated as 0.72 years but an absolute age of 0.845 for fishes of age 0 group was assumed. If 1 year absolute age for 0 group is assumed, then age at first maturity is 0.88 years and natural mortality rate from Rickhter and Efanov (1976) empiric model would be 1.4, the same as estimated with catch at age curve analysis.

Mortality rates estimated with the empiric models of Pauly (1980) and Cubillos (2003) were lowest. But the problem is that those models use von Bertalanfy parameters which was not the best model describing growth in this study. The Hewitt and Hoenig (2005) model is the simplest and uses only maximumum observed age. In this study, maximumum observed age was 6, and natural mortality was 0.75 $year^{-1}$ but an increment of 1 year of maximumum age could result in a 0.64 $year^{-1}$ rate.

Assuming total mortality of 1.4 $year^{-1}$ (from catch at age curve analysis) and natural mortality rates of 1.4 and 0.75 (from corrected Rickhter and Efanov (1976) and Hewitt and Hoenig (2005)) an “exploitation rate” of 0 to 0.46 is obtained. This means that the “health” of the stock of Chame *D. latifrons* is good, considering the 0.5 exploitation rate as reference point for overexploitation.

D. latifrons is a r-strategist species as revealed by its high fecundity, early age and low size at first maturity. It is associated with floods for dispersal to habitats such as streams, seasonal ponds, estuaries and coastal lagoons. Differences between total and natural mortality rates reveals added mortality from other sources than this life history reveals. Human constructions in the beds of rivers and streams that stop the migratory routes of the species, changes in duration of the dry season, fisheries and shrimp aquaculture were major factors identified that could added this mortality. Despite their high resistance to extreme environmental conditions, a long dry season can reduce the seasonal freshwater lagoons that remain after floods, resulting in total mortality for local stocks as was seen in Mataderos lagoon. Although no fishery is directed at *D.latifrons*, fish mortality most likely results from the shrimp fishery in coastal lagoons. An estuary called “Puyeque” (the common name of chame in the region) is thus named because a lot of *D. latifrons* are caught as bycatch when the shrimp fishery season begins. A lot of chame fishes are disposed of on the shores of the estuaries and coastal lagoons where they decompose without anyone using them as food. *D. latifrons* is common in the ponds and channels of shrimp farms were they compete with shrimp for food. Farmers capture and discard them. This added mortality is very important as revealed in the estimated “exploitation rate”. Even without a commercial fishery for chame in the region, the “exploitation rate” is the same order of magnitude for targeted fisheries species in the region. A management plan is necessary for conservation of the species. Its high fecundity and rapid growth rate could be exploited for aquaculture purposes.

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