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ASSESSMENT OF THE PRESENT CAPACITY FOR MANAGEMENT OF THE LOCO *CONCHOLEPAS CONCHOLEPAS* (BRUGUIERE, 1789) (GASTROPODA, MURICIDAE) IN CHILE

EVALUACION DE LA ACTUAL CAPACIDAD DE MANEJO DEL LOCO *CONCHOLEPAS CONCHOLEPAS* (BRUGUIERE, 1789) (GASTROPODA, MURICIDAE) EN CHILE

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ABSTRACT

In recent years the fishery for loco (*Concholepas concholepas*) has undergone a number of changes in management strategy. The first was a change in the minimum size limit from 95 mm in the north of Chile and 105 mm in the south to a uniform 100 mm in 1981. An annual 3 month closed season was initiated in 1982, and, starting in September of 1985, there was a closure of nearly two years in all regions except the southernmost three. This two-year closure has been followed by two short open seasons, one of 45 days in 1987, and one with a national 5,000 ton quota in 1988. The response by fishermen to increasingly restrictive regulation has been some clandestine fishing and the stockpiling of locos prior to the open season. These actions have resulted in the partial loss of landings data and a nearly total loss of meaningful effort data. This loss of data will have serious impact on the ability of fishery managers to effectively evaluate the state of the fishery and determine future regulatory actions.

There is considerable published background information on the basic biology of the species, and some information on aspects of the population dynamics such as growth and mortality. There are, however, large discrepancies between authors which may be due to sub-population or regional differences. There is also a complete lack of information on loco recruitment. As a result, a number of management model options are unavailable, and there is no present capability to evaluate the effect of decreasing stocks on recruitment levels, or the potential of recruitment over-fishing. The development of a recruitment index is further hampered by a lack of information and proven sampling techniques for the earliest life stages of the loco.

In October of 1988, CONICYT (Comisión Nacional de Investigación Científica y Tecnológica) sponsored a symposium to assess the present state of knowledge on biotechnology, aquaculture, repopulation and population dynamics of the loco. In this paper we review the available literature pertinent to the population dynamics and management of the loco, including aspects of life history and ecology. We examine the present potential for management, and suggest some areas of investigation which may provide a basis for the future management of the resource. The need for improved levels of catch and effort data, and the need for education and improved communication between fishery managers, industry and fishermen is also discussed.

Key words: Concholepas, *loco, population dynamics, growth, mortality, management.*

RESUMEN

En años recientes, la pesquería del recurso loco, *Concholepas concholepas*, ha pasado por una serie de cambios respecto a la estrategia de manejo. El primero fue un cambio en el tamaño mínimo de extracción, desde 95 mm en el norte del país y 105 mm en el sur, a un tamaño uniforme de 100 mm. Una veda anual de tres meses se implantó en 1982 y a partir de 1985 se implementó una veda de casi 2 años en todas las regiones del país, con excepción de las tres más sureñas. A esta veda de dos años le siguieron dos períodos cortos de pesquería, uno de 45 días, en 1987, y uno con una cuota nacional de 5.000 toneladas en 1988. Las respuestas de los pescadores artesanales al incremento de las medidas restrictivas para la pesca de este recurso, han sido la pesca clandestina y el "apozamiento" o almacenamiento de locos bajo el agua, en

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períodos previos a las aperturas de las vedas. Estas acciones se han traducido en una pérdida parcial de los datos de desembarques y en una pérdida casi total de información sobre esfuerzo de pesca. Estas pérdidas de información tendrán en el futuro serios impactos en relación con la habilidad de manejadores pesqueros para evaluar efectivamente el estado de la pesquería y determinar medidas de regulación futura.

Existe una considerable cantidad de publicaciones sobre la biología básica de esta especie e información más restringida sobre aspectos de dinámica poblacional, tales como crecimiento y mortalidad. No obstante, existen fuertes discrepancias entre diferentes autores. Estas pueden deberse al trabajo con diferentes subpoblaciones de locos o a diferencias de tipo regional. Por otra parte, la información sobre el reclutamiento del loco es insuficiente o parcialmente inexistente. Como resultado de lo anterior, un número importante de modelos de manejo no son posibles de ser utilizados y en estos momentos no existe una capacidad para evaluar el efecto del decremento de los stocks sobre los niveles de reclutamiento o el potencial efecto de la sobrepesca sobre el reclutamiento. El desarrollo de un índice de reclutamiento es más grave aún, debido a la falta de información y técnicas confiables en el muestreo de los estados tempranos (larvales) del loco.

En octubre de 1988, CONICYT (Comisión Nacional de Investigación Científica y Tecnológica) organizó un Simposio con el fin de evaluar el estado actual del conocimiento sobre biotecnología, maricultura, repoblación y dinámica poblacional del loco. En este trabajo nosotros presentamos una revisión de la literatura disponible y pertinente a la problemática de la dinámica poblacional y manejo del loco, incluyendo aspectos biológicos sobre sus estados tempranos y ecología. Examinamos el potencial del conocimiento actual para el manejo pesquero y sugerimos algunas áreas de investigación que pueden aportar las bases para el manejo futuro del recurso. Se discute la necesidad de mejorar la información referente a la captura y esfuerzo, educar y mejorar las comunicaciones entre manejadores, industriales y pescadores artesanales.

Palabras claves: Concholepas, *loco, dinámica poblacional, crecimiento, mortalidad, manejo.*

INTRODUCTION

The muricid gastropod loco (*Concholepas concholepas*) is one of the most important species taken by artisan fisheries in Chile. This abalone-like species is considered a delicacy, and is in high demand in numerous countries outside Chile, making it an economically important export. The Chilean loco fishery is among the worlds most important gastropod fisheries, and ranked first in that category in 1984 (Bustamante and Castilla, 1987).

The most effective method of harvesting the sub-tidal, adult populations of this species is by hooka divers from small boats, so the loco has not become the object of large scale commercial operations. Most harvesting is done from open boats (7 to 10 meters) by artisan fishermen and divers. The high price and ready marketability of the loco make it an important economic component in the lives of these individuals.

From 1965 until 1981 the only restriction on harvesting locos was a minimum size of 95 mm in Regions I through IV, and 105 mm in the rest of Chile. In 1981 a nationally uniform minumum of 100 mm was established (Castilla and Jerez, 1986). In 1982, a 3 month closed season from March 1 through May 31 of each year, was instated. This additional restriction was in force in 1982, 1983, 1984 and 1985. An anomalous decline in the catches shortly after the start of the 1985 season, and the occurrence of large numbers of locos below the 100 mm size limit, triggered a two year closure of the fishery, from September 25, 1985 to May 15, 1987, in all regions except the southernmost three (X, XI and XII, Fig. 1). The south was exempted from closure because it was presumed to have been historically under-exploited.

The fishery reopened for 45 days on May 15, closing on June 30, 1987 in all regions including the south. A second season with a 5 thousand ton national quota was initiated on June 16, 1988. This quota was exceeded in 6 days, and the fishery closed on July 21, 1988. During these latter 2 seasons a large proportion of the catch was taken by fishermen prior to the opening date, and held in the ocean in mesh bags to be landed during the open season. In the 1987 season the number of locos taken early and held was probably half of the total number of locos landed in the season. In the 1988 season, nearly all of the locos landed had been taken prior to the opening date.

The quota of 1988 was filled quickly because the fishermen started stockpiling locos well in advance of the opening date. This early taking and stockpiling of locos, called "apozamiento", resulted in a decreased quality of locos during the 1988 season, and in some areas, considerable mortality. Locos can apparently be held without appreciable decrease in quality for several weeks, and can survive for a month or more. The 1988 season was initially set to open on May 15, 1988, so apozamiento was initiated some weeks prior to this date in many areas. The opening date was later postponed to June 15, which caused the holding of many locos for well over a month, and resulted in high mortalities.

The phenomenon of apozamiento has been observed in each of the opening dates since 1983, but the locos taken prior to the opening date have generally been landed within the first one to three days of fishing. The more recent, shortened, seasons have seen a large increase in apozamiento, all of which represents undocumented effort in the landings. Studies of the population dynamics and the development of management plans for the loco have traditionally relied on catch and effort data obtained from the artisan fishery. The loss of effort data will complicate future studies of population dynamics, and has been further aggravated by attempts by the fishermen to control the price of locos by withholding even catches made during the fishing season.

It seems unlikely that the problem of apozamiento of locos can be easily overcome, though it may be reduced. The fishermen are aware that a season may last less than a week, and this is not sufficient time to capture appreciable quantities of this economically important species. However, locos held for many weeks suffer a notable decrease in quality, and there is considerable opposition to this practice by commercial processors. Pressure by processors and regulatory personnel may help to shorten the periods of apozamiento, but it is doubtful that the practice can be eliminated.

In addition to the problem in data collection represented by apozamiento, there has been an appreciable clandestine fishery for loco operating during the closed season. The clandestine landings represent an additional, and potentially very large, undocumented catch and effort. There have been no published estimates of the magnitude of clandestine fishing.

In view of these recent developments in the loco fishery, efforts are being made to seek innovative techniques in its management and to seek alternative measurements of the status of the loco populations. Our objectives in this paper are to review the published information on the loco, examine the present potential for management, and to suggest some areas of investigation which may provide a basis for the future management of the resource.

LITERATURE REVIEW

Frequent reference will be made in the text to the region (Fig. 1) in which studies were conducted. Table 1 lists the field study site for most of the authors cited.

ANNUAL CYCLES AND EARLY LIFE HISTORY

Aspects of the annual life cycle of the loco have been documented by numerous authors. Avilés and Lozada (1975) found a high percentage of males to be sexually active virtually all year in Region IV, while the percentages of sexually active females rose gradually through the winter months to peak in October. Ramorino (1975) found sexually ripe individuals from December to June in Region V, peaking in February and March, and associated the stages of annual gonad development with ocean tempertures. Ramorino also noted that some mature individuals occurred all year.

Copulation is accompanied by the formation of groupings of locos, called "maicillos", or "flor del loco", which are in turn followed by the egg capsule deposition (Schmiede and Castilla, 1979; Castilla, 1979 and 1982). The degree of aggregation was evaluated using Morisita's index by Schmiede and Castilla (1979), and ranged from lows of near 1, indicating near random dispersion, to peaks of 7 in October and 8.5 in February in Region IV. The maximum number of locos observed in a subtidal grouping was 1,340. The October peak consisted primarily of individuals under 100 mm, and the February peak of individuals over 100 mm. Schmiede and Castilla (1979) also detected movements to shallower areas during the periods of reproductive groupings for both the smaller individuals in October and the larger individuals in February, and suggest that these movements may bias length frequencies taken in different times of the year.

The formation of these reproductive groupings, or maicillos, probably increases their catchability, and the determination of the period for the 3 month seasonal closures from 1982 to 1985 was based in part on this premise. Ramorino (1976) reported a primary spawning period from January to July

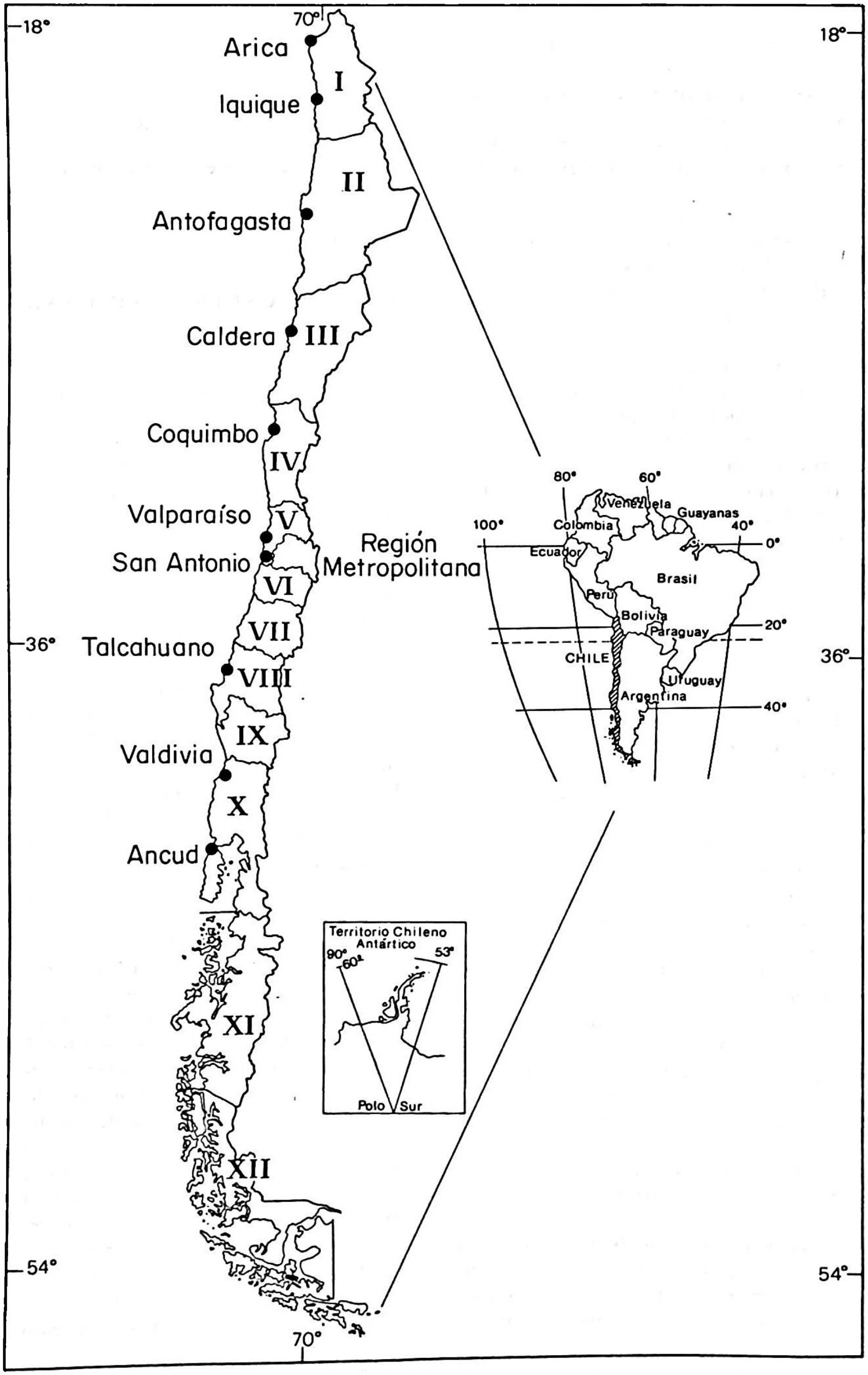

Figure 1. Map of Chile indicating the national regions and major cities nearest to field study sites of the loco (*Concholepas concholepas*).

Table 1
Study locations of authors cited in this paper. See map (Figure 1) for the geographical location of regions and major cities

Authors, Year	*Site*	*Region*	*Nearest Major City*
Acuña and Stuardo, 1979	Montemar	V	Valparaíso
Adlerstein, 1986	Hornos	IV	Coquimbo
Avilés and Lozada, 1975	Pta. Saliente	IV	Coquimbo
	Bahía Herradura	IV	Coquimbo
Bustos *et al.*, 1986	Ancud	X	Ancud
Bustos *et al.*, 1985	Ancud	X	Ancud
	Caldera	III	Caldera
Castilla, 1979	Hornos	IV	Coquimbo
	Bahía Herradura	IV	Coquimbo
	Los Molles	V	Valparaíso
Castilla and Durán, 1985	Las Cruces (ECIM)	V	San Antonio
Castilla *et al.*, 1979	Las Cruces (ECIM)	V	San Antonio
	Bahía Herradura	IV	Coquimbo
	Los Molles	V	Valparaíso
	Hornos	IV	Coquimbo
Castilla and Jerez, 1986	Las Cruces	V	San Antonio
	El Quisco	V	San Antonio
	Quintay	V	Valparaíso
	Isla Pájaros	IV	Coquimbo
DiSalvo, 1988	Bahía Herradura	IV	Coquimbo
Durán *et al.*, 1987	Las Cruces (ECIM)	V	San Antonio
Gallardo, 1973	Mehuín	X	Valdivia
Guisado and Castilla, 1983	Las Cruces (ECIM)	V	San Antonio
Geaghan and Castilla, 1986	Cruz Grande	IV	Coquimbo
	Quintay	V	Valparaíso
Geaghan and Castilla, 1987	El Quisco	V	San Antonio
	Hornos	IV	Coquimbo
Herrera and Alvial, 1983	Huayquique	I	Iquique
Jerez and Rivas, 1988	Ancud	X	Ancud
Lépez, 1987	Mehuín	X	Valdivia
Lozada, E. *et al.*, 1976	Cta. Leandro	VIII	Talcahuano
	Pta. Saliente	IV	Coquimbo
Moreno *et al.*, 1986	Mehuín	X	Valdivia
Oliva and Castilla, 1986	Las Cruces (ECIM)	V	San Antonio
Ramorino, 1975	Valparaíso	V	Valparaíso
Rivas and Castilla, 1987	Las Cruces (ECIM)	V	San Antonio
	Quintay	V	Valparaíso
	Montemar	V	Valparaíso
Schmiede and Castilla, 1979	Hornos	IV	Coquimbo
Tobella, 1975	Caleta Leandro	VIII	Talcahuano

and a smaller, secondary spawning period in October and November. The reproductive groupings are observed from February to May in Region V, and the grouping period is followed by the peak period of capsule deposition and development from March through July in Region IV.

The eggs are laid in capsules, attached to rocky substrate, in intertidal and sub-tidal areas. Castilla (1979) reports that the greatest masses of capsules are deposited in the lower intertidal and shallow sub-tidal areas. Ramorino (1975) found egg capsules most abundant in February to May, but reports that capsules can be found all year in Region V. Gallardo (1973) states the capsules are available in Region X from November through March.

Castilla and Cancino (1976) and Castilla (1979) demonstrate linear relationships between the length of the capsule and the size of the female depositing the capsules and between capsule length and thousands of larvae in the capsule. Several females kept in the laboratory produced in excess of 200 capsules in a year, and the range of eggs per capsule was 668 to 14,250 (Castilla and Cancino, 1976). Ramorino observed up to 256 capsules deposited in three stages by a single female, with numbers of eggs per capsule ranging from 3,288 to 9,450, while Gallardo (1973) found from 2,450 to 14,250 eggs per capsule. Hatching occurs in 60 to 84 days in eggs kept at 12 to 14°C, the range observed in the sea (Ramorino, 1975). Castilla and Cancino (1976) observed hatching in 69 to 128 days at temperatures ranging from 13.5 to 14.5, while Gallardo (1973) obtained hatching in 36 to 37 days, but at higher temperatures, ranging from 16 to 22°C.

The larval stages of the loco are planktonic, a stage that has been shown to last as long as 3 months under laboratory conditions (DiSalvo, 1988), though it is probably less under natural conditions. Metamorphosis occurred at 1.4 to 1.7 mm.

After metamorphosis, the post larval locos settle in the rocky intertidal zone. The substrate inhabited by recently settled locos is described by Castilla *et al.* (1979) for recently settled locos with a mean size of 1.605 mm. As the locos mature, they emigrate to subtidal areas. Castilla (1982) indicates that movements from the intertidal to sub-tidal areas probably start at about a year of age. Rivas and Castilla (1987) estimate the instantaneous rate of emigration from the intertidal population to be 0.67, assuming that the intertidal rate of natural mortality for juveniles is 0.20, the same as that estimated for adults.

Distribution and fishing mortality for intertidal juvenile populations have been estimated by Rivas and Castilla (1987). The instantaneous rate of fishing mortality was estimated to be between 0.92 and 1.51, and is due primarily to "mariscadores", local residents who derive a part of their subsistence from intertidal shellfish gathering. Estimates of intertidal densities of loco published by Durán *et al.* (1987) indicate that a reduction from 4.3 locos per m in protected areas to 1.4 per m in harvested areas is due to mariscadores. The total annual harvest of 5.4 locos per m is apparently supplemented by seasonal displacement of locos from the subtidal to intertidal habitats (Durán *et al.*, 1987; Castilla and Durán, 1985). Moreno *et al.* (1986) and Oliva and Castilla (1986) have published additional information on the effects and intensity of intertidal fishing by mariscadores on the loco and other species. The impact of the mariscadores as a factor in loco population dynamics is apparently quite great, and has not previously been taken into account.

GROWTH RATES AND MATURATION

In Region V first year growth has been reported as 3 mm per month by Acuña and Stuardo (1979), 3 mm per month for individuals under 47 mm by Tobella (1975) in Region VIII, and 3.67 mm for newly settled individuals averaging 11.3 mm in Region V (Guisado and Castilla, 1983). Monthly growth rates for recently settled locos in the rocky intertidal areas have been reported as 3 mm in Región X (Lozada, *et al.*, 1976). Lépez (1987), using tagged individuals in Region X, found that the growth rate of intertidal populations of locos are seasonal. Lépez gives the winter (May through September) rate of growth as 1.23 mm, almost half of the summer rate (October through January) of growth of 2.14 mm per month.

The size at sexual maturity was determined using histological sections by Avilés and Lozada (1975). No sexually mature individuals were found with lengths under 50 mm. Individuals from 50 to 70 mm were found to be maturing while those over 70 mm were mature. Herrera and Alvial (1983) determined the minimum size of sexual maturity as 49 mm for males, and 53 mm for females. The size at which 50 percent of the population was mature was in the 57 to 62 mm length class for both sexes. If maturity is taken to occur at 60 mm, then sexual maturity is reached at approximately two years of age.

Several estimates of parameters of the von Bertalanffy growth curve have been published for the loco (Table 2). Castilla and Jerez (1986) determined growth from length frequencies, and obtained estimates for several sites in Central Chile (Regions IV and V). Bustos *et al.* (1986), using ages determined from external shell examinations, reported a parameter estimates for a modified version of the von Bertalanffy growth curve (with a power term of 1/D) for southern Chile (Region X). In a report to the Corporación de Fomento de la Producción, Bustos *et al.* (1985) reported figures for Region III (Caldera) and Region X (Ancud).

An additional growth model was estimated for locos from Caleta Hornos, in Region IV by Adlerstein (1986). This model was based on aged locos employing shell sectioning techniques and the analysis of micro-growth rings. Adlerstein detected fortnight and annual periodicities, and

Table 2
Published values of parameter estimates for the Von Bertalanffy growth curve estimated from subtidal populations of the Chilean loco

Authors	Area (Region)	n	L_∞	K	t_0
Castilla and Jerez (1986)	Las Cruces (V)	193	183.098	−0.203	−0.023
Castilla and Jerez (1986)	Las Cruces (V)	166	167.150	−0.215	−0.012
Castilla and Jerez (1986)	El Quisco (V)	606	172.534	−0.229	−0.014
Castilla and Jerez (1986)	Quintay (V)	308	168.241	−0.202	−0.035
Castilla and Jerez (1986)	Combined (V)	—	175.247	−0.212	−0.021
Castilla and Jerez (1986)*	Montemar (V)	105	175.25	−0.161	−0.102
Bustos *et al.* (1986) (D=0.4)	Ancud (X)	2,049	189.39	−0.34771	5.0689
Bustos *et al.* (1985)	Caldera (III)	1,809	177.66	−0.09355	2.332229
Bustos *et al.* (1985)	Ancud (X)	2,097	229.54	−0.07730	1.889274
Adlerstein (1986)	Hornos (IV)	101	131.40	−0.362	0.491
Lépez (1987)	Mehuín (X)	—	201.00	−0.12	—

*Data from Acuña and Stuardo (1979).

spawning checks deposited in late summer and early spring. Adlerstein also suggests that the growth pattern may follow, at least initially, a Gompertz type growth curve, but decides in favor of using the von Bertalanffy growth function.

The mean length of time needed to reach the commercial size of 100 mm has been estimated as 3.5 years (Adlerstein) for Region IV, and in Region V as 4 years in Quintay (Castilla and Jerez, 1986), and as between 4 and 5 years by Acuña and Stuardo (1979). In Region X, Bustos *et al.* (1986) estimated commercial size as occurring at between 5 and 6 years, while Lépez (1987) estimates that commercial size is obtained in 6 years (1984 growth rates) or more (1985 growth rates) for tagged intertidal specimens.

Castilla and Jerez (1986) estimated the critical size using the equation of Alverson and Carney. In all of the cases examined, the critical size exceeded the 100 mm size limit presently in effect. The values, calculated with a natural mortality of 0.20, ranged from 120 to 129.

Mortality parameter estimates

Several estimates of natural and fishing mortality, calculated with a variety of techniques, have been published. Castilla and Jerez obtained various estimates (Table 3a) using the method of vanSickle (1977) for sites in Regions V to obtain estimates of the total mortality (Z). These authors applied the same technique to samples of nearly virgin populations from isla Pájaros (Region IV) to obtain estimates of the maximum value of natural mortality. Geaghan and Castilla (1986, 1987) employed a modified version of the Leslie model (incorporating natural mortality and recruitment) to obtain estimates of natural mortality (M) and the catchability coefficient (q) (Table 3b). An additional estimate of fishing mortality of 0.97 is provided by Jerez and Rivas (1988) for Region X (Table 3b).

Recruitment

In studying the dynamics of fished populations, it is necessary, at a minimum, to

Table 3a
Published values of parameter estimates for natural mortality (M) and total mortality (Z) based on length frequencies for the Chilean loco

Authors	Area (Region)	n	M	Z
Castilla and Jerez (1986)	Isla Pájaros (IV)	—	0.2; 0.23	—
Castilla and Jerez (1986)	Las Cruces (V)	193	—	1.277
Castilla and Jerez (1986)	Las Cruces (V)	166	—	1.817
Castilla and Jerez (1986)	El Quisto (V)	1,120	—	1.956
Castilla and Jerez (1986)	Quintay (V)	2,434	—	1.876
Castilla and Jerez (1986)*	Montemar (V)	105	—	2.103

*Average for various sub-populations.

Table 3b
Published values of parameter estimates for natural mortality (M), fishing mortality (F) and catchability coefficients (q) for the Chilean loco

Authors	Area (Region)	M	F	q
Geaghan and Castilla (1986)	Quintay (V)	0.147	1.727	−0.0001034
Geaghan and Castilla (1986)	Cruz Grande (IV)	0.194	2.146	−0.0000726
Geaghan and Castilla (1987)	Hornos (IV)	—	—	−0.0001334
Geaghan and Castilla (1987)	El Quisco (V)	—	—	−0.0000964
Jerez and Rivas (1988)	Ancud (X)	0.154*	0.97	—

*Bustos (1986) in Jerez and Rivas (1988). The value of M is given as a mean 0.154 s. deviation 0.043.

understand and measure the major additions to and losses from the population. This would include natural and fishing mortality as losses, and growth and recruitment as additions. As listed above, there is an appreciable amount of information available on mortalities and growth. However, there is very little information on recruitment. The habitat used for recently settled post larval locos and growth rates have been described by Guisado and Castilla (1983) and Lépez (1987). The pattern of juvenile distribution, mortalities and movements have been discussed by Rivas and Castilla (1987).

Mean daily rates of recruitment have been estimated for four fished populations (Geaghan and Castilla, 1986, 1987). In Region IV daily rates of recruitment were estimated as 2,866 for the fishing village of Hornos and 5,370 for Cruz Grande. In Region V estimates were 1,732 for Quintay and 1,438 for El Quisco. Since these fished populations are specific areas, each with its own surface area and capacity to support locos, figures for these sites cannot be readily generalized to other fished populations. These estimates were also made for specific time intervals, and may not reflect the recruitment potential of present population levels.

There is no additional information on recruitment levels or recruitment potential. Durán and Castilla (1988), based on laboratory observations, have estimated size specific fecundity for locos in Region V. To date there have been no efforts to relate recruitment levels or the size of prerecruit life stages to adult population levels.

DISCUSSION

In the winter of 1985, during the first months of the 1985/86 season, there was a sharp, anomalous reduction in the catch of locos and the occurrence of smaller sizes in the catch. A two year closure was initiated in September of 1985 to prevent growth over-fishing. Growth over-fishing as described by Gulland (in Lackey and Nielsen, 1980) refers to a fishery where small individuals are taken incidentally in an intensive fishery. This results in an inefficient, non- optimal exploitation of the fishery. Gulland states that the obvious solution is to "prohibit the landing or retention on board of small fish", and that this is "possible in a few cases, notably when each animal is taken individually". If sizes cannot be controlled, then effort is reduced to increase the overall life span and thus optimize the harvest.

Locos are taken individually by divers. In many areas, the divers do an excellent job of judging and selecting legal sized locos. Therefore, the appearance of smaller individuals in the loco fishery, particularly in 1985, was due to a change in criteria by the divers and fishermen, and was probably a result of increasing demand and decreasing supply. The appropriate course of action would be better enforcement and education of the fishermen. But, more important, even if growth over-fishing was present, this type of over-fishing alone is not likely to lead to a collapse in the fishery. The problem is primarily one of inefficiency in terms of optimizing the harvest.

Much more serious consequences can result in a fishery that experiences recruitment over-fishing. Gulland (in Lackey and Nielsen, 1980) states that this occurs when the "adult stocks are reduced to the level at which there is a significant fall in the average recruitment", and that this type of over-fishing is "much more serious than growth over-fishing and can lead to the complete collapse of the fishery". He also notes that this type of over-fishing is much harder to detect, and that its control would often justify "a very substantial and rapid reduction in catches".

The partial recovery in the loco populations following the closure, discusses below, and evidence from closed areas (see Moreno and Reyes, 1988 and Castilla, 1988) indicates that the loco probably did not suffer from a complete collapse of recuitment. However, present rates of recruitment may be reduced in comparison to previous years, and may have contributed to the sharp declines observed in 1985. Numerous hypotheses can be stated to potentially explain the 1985 decline in catches in addition to a reduced rate of recruitment due to recruitment overfishing, such as reduced population levels due to clandestine fishing or reduced recruitment for some transitory reason (reduced growth). However, it is of the utmost importance to guarantee that recruitment over-fishing does not occur in the future. Some index or measure of recruitment will be needed.

The Fishery

The total production in Chile (Figure 2, insert) averaged about 4,000 t from 1956 through 1971, and after 4 years of catches averaging 5 to 6 thousand t increased rapidly to nearly 25 thousand t in 1980. Since 1980, the loco catches have decreased rapidly, though the generally lower catches since 1985 may be the result of shortened seasons. The sustained catches observed from 1956 through 1971 would suggest that a quota should be at least 4,000 t, and something less than 25,000. Jerez and Rivas (1988) calculate a conservative estimate of 5,000 t for the 1988 season, which is probably a good initial level in view of the uncertainty associated with the fishery in 1987.

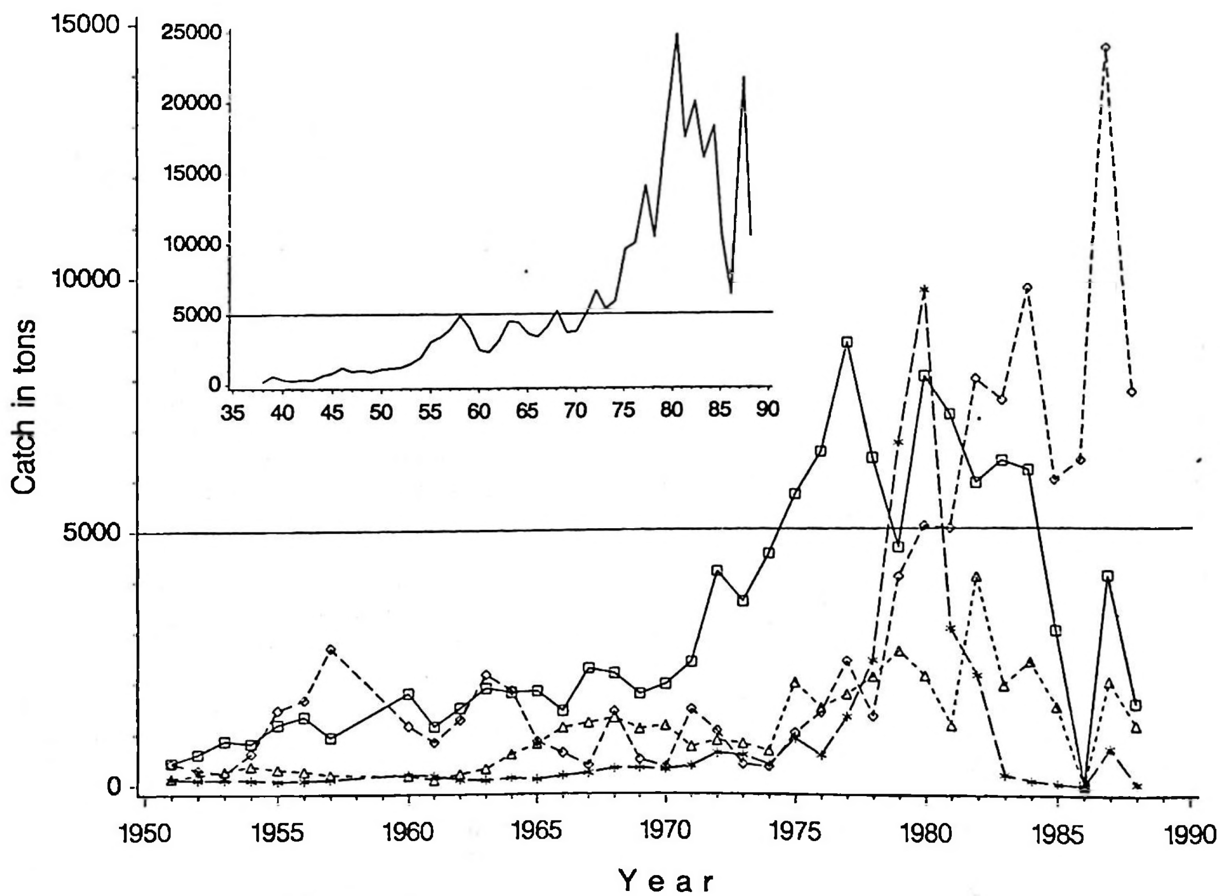

Figure 2. **Annual catch in tons of loco (*Concholepas concholepas*) for all of Chile (inset) and separately for four geographical subdivisions; Northern (Regions I-II: •), Central (Regions III-VI: □), South-Central (Regions VII-IX: △) and the South (Regions X-XII: ⋇). The database, provided by SERNAP, the Chilean National Fishery Service, contains preliminary figures for 1988.**

Examination of grouped regions (Figure 2) suggests that the best quota may be considerably more than the 4,000 t indicated by the annual catch data. The central regions of Chile (zones III, IV, V and VI) and the southern regions (particularly zones X and XI) were probably under-exploited during most of the years included in the catch statistics. The central regions provided a sustained yield of approximately 2,000 t from 1960 through 1972, and a sustained yield of over 5,000 t from 1975 through 1984. This suggests that, barring changes in recruitment levels, the quota for the central region should be at or above the 5,000 t level.

During the period between 1960 and 1978, the southern region generally produced less than 2,000 t annually. Since 1979, the yield from the southern region has increased dramatically to around 8,000 t annually. Much of this production has resulted from the exploitation of virgin fishing grounds as fishermen, principally from zone X, have fished further south into zone XI. To what extent the present levels of exploitation can be sustained is unknown.

The region encompassing zones VII through IX have had a stable production of 1 to 2 thousand t since 1960, and has generally produced in excess of 2,000 t since 1975. The 2,000 t level appears to be sustainable.

The most variable region is northern Chile (zones I and II). This area provides little production, generally under 1,000 t. However, it rose from under 1,000 t in 1976 to 10,000 t in 1980, and returned to under 1,000 t by 1983. The high production, observed in 1980 is the primary cause of peak in national production observed in that year. Discussions during this symposium suggested that variations in loco productivity in northern Chile may be the result of variations in environmental factors, especially the capricious El Niño current. If this proves to be true, this area should be treated as a special case in future management plans.

If the apparently sustainable levels discusses above from the SERNAP landings data are correct, regions III through IX alone should provide 7,000 t annually. The southern regions should be capable of sustaining a level of production of at least 3 to 4 thousand t, suggesting a sustainable national level of in excess of 10,000 t annually, plus any production from northern Chile.

Figure 3 shows the average catch per boat days for four fishing villages in central Chile (Regions IV and V) as both means for 100 boat days of effort and the simulations from Geaghan and Castilla (1987). The record is not complete for any one area, but the parallel pattern of the existing station records suggests that the pattern would generally reflect the catch per unit of effort for the central region. Also, the Chilean artisan fishermen have shown themselves to be quite mobile, so it seems unlikely that individual areas would maintain higher than average catch rates for very long.

Assuming that Figure 3 is representative of catch rates for central Chile, there are several observations that can be made. First, the sharp drop in 1982 was the direct result of increased fishing effort (Geaghan and Castilla, 1986 and 1987). The sharp drop appears to be associated with the first 3-month closed season in 1982, and possibly resulted from increased demand and prices following that closed season.

Since that decreasing yield per boat was accompanied by an increase in effort, the total production from central Chile has not decreased proportionally, declining from about 8,000 t in 1980 to 6,000 t in 1984 (Figure 2). The subsequent declines evidenced in Figure 2 are the likely result of catch restrictions in effect since 1985, and not due to additional declines in catch rates. In fact, available evidence from the 1987 season (Figure 3) indicates that catch rates increase from a low of about 200 locos per boat-day in 1985 to 500 locos per boat-day in 1987. The higher catch rates predicted by simulation models (Geaghan and Castilla, 1986 and 1987) do not take into account clandestine fishing or possible reductions in recruitment.

The most disturbing trend in Figures 2 and 3 is the apparent large drop in population densities in 1982, as evidenced by decreasing catch per unit of effort. The decreasing densities alone are not necessarily a problem, if it were certain that the existing populations could maintain production. However, with virtually no knowledge of recruitment capability, the reduced populations must be a concern to fishery managers. The sharp drop in catch per unit of effort in the winter of 1985 may have resulted, at least in part, from reduced recruitment.

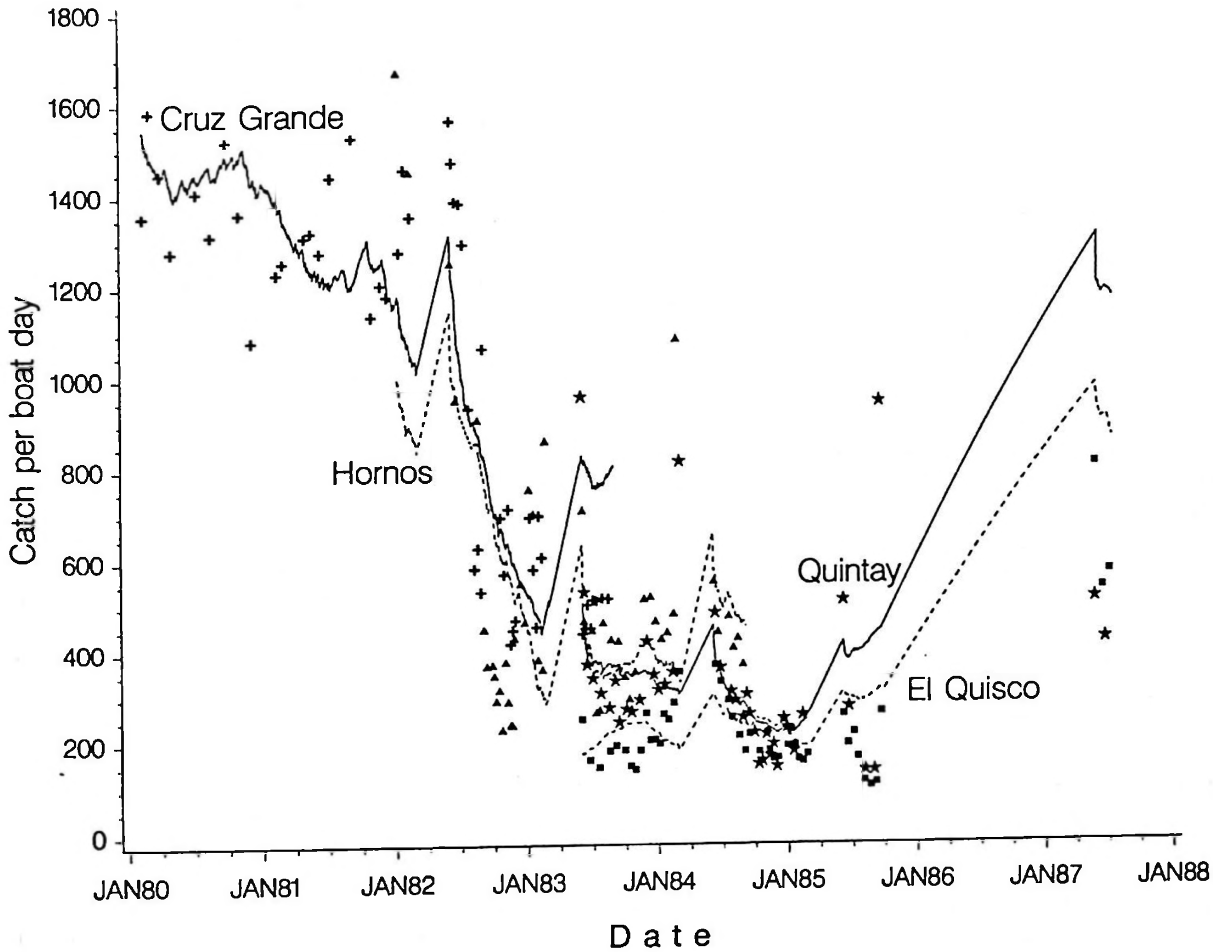

Figure 3. Catch per unit of effort of loco (*Concholepas concholepas*) per boat-days for four fishing villages in Central Chile; Cruz Grande (Region IV: +), Hornos (Region IV: △), Quintay (Region V: ★) and El Quisco (Region V: □). Individual data points represent the mean of approximately 100 boat-days of effort. Solid lines are simulations from Geaghan and Castilla (1987) with additional projections beyond 1986 for Quintay and El Quisco.

Management alternatives

Assuming that a policy of open entry to the fishery is maintained, there are several obvious choices of action. One extreme would be a complete closure of the fishery to insure recovery. This choice is reasonable only if necessitated by recruitment over-fishing. The other extreme would be to open the fishery entirely, an option that could result in extremely inefficient exploitation of this open access fishery.

Two more reasonable choices are to continue with an annual quota, refining this over time to an optimum level, or to reopen the fishery for an extended period of time, from several months to a year or more, probably maintaining the annual 3 month closed season. Each fo these courses of action have consequences for the fishermen, industries and the resource.

The quota system of management has several strong advantages for the loco fishery. It should limit the fishing levels, which is critical if recruitment over-fishing exists. It is also relatively easy to enforce, insofar as regulations of the loco fishery can be enforced. Unfortunately, clandestine fishing may negate many of the advantages of the quota system, or any other attempt to limit fishing effort.

The 1988 quota was set nationally at 5,000 t. The fishery was closed after 6 days of landings, almost all of which had apparently been stockpiled prior to the opening date. The quota was also exceeded by at least 100 percent. Preliminary data from SERNAP, the Chilean National Fishery Service, places the total 1988 landings at over 10,000 t. Therefore, as a result of stockpiling, or apozamiento, any quota up to 10,000 t, as evidenced by the 1988 experience, is likely to be filled in a week without any possibility of documenting effort.

The SERNAP landings data includes locos landed during the 6 day open season, including those which were apozados. However, clandestine landings which are not seized by SERNAP are not included, so the annual total landed exceeds the SERNAP figure by an unknown amount.

The calculation of the 1988 quota was bases on estimates of catchability from fishing grounds in Region X. Estimates were bases on 12 sub-populations, presumed to be banks of locos, selected from 60 sub-populations fished by fishermen from 3 villages. A relatively conservative estimate of the growth rate, 0.9, was used in recruitment calculations from Bustos *et al.* (1985), along with a natural mortality estimate of 0.2, were used estimating production. These calculations for southern Chile were subsequently expanded to a national level.

In order to evaluate this approach, independent estimates of recruitment are needed. It is also necessary to determine if growth, mortality and recruitment parameter estimates from a single region are adequate to determine quotas at a national level. The 5,000 t quota would appear conservative in view of the historic levels examined by grouped regions presented earlier. In fact, the observed production of 10,000 t, 100percent over the quota,appears to be a more reasonable level. It is possible, if future quotas are exceeded by 100 percent, that an artificially low quota must be designated to obtain the desired level. However, it seems unlikely that 10,000 t would be stockpiled again to fill future quotas, in view of the low quality and mortalities observed in 1988. Furthermore, managers would risk a loss of credibility in setting an artificially low quota.

The quota system of management is not necessarily the most efficient approach, in terms of obtaining an optimal harvest level. The desirability of this approach depends on the ability to enforce the established quota, and the availability of sufficient information to establish an optimal quota. The quota has an additional disadvantage in that regional quotas are difficult to manage, and a national quota may still result in over-fishing in some areas and underfishing in others. The quota system also yields very irregular production levels for the fishermen and industries, with the total annual production being produced in 6 days in the case of the loco. Finally, if the quota is filled quickly, less than a month, then there is little or no data available to evaluate densities and modify the quota in the future. In the case of the loco, the quota system, if maintained, means an almost total loss of catch and effort data.

An alternative is to reopen the fishery for an extended period of time. Reopening the fishery would almost certainly result in a repeat of the pattern observed in 1982, with rapidly falling catches following the opening date. The 45 day open season of 1987 produced near optimal levels, and perhaps half of the catch was taken during the season, with the other half resulting from stockpiling. This pattern, if it could be repeated with a 45 to 60 day season, would likely provide adequate estimates of catch and effort to evaluate stocks. Also, if the fishermen could be guaranteed a longer season, as opposed to 6 days, there would perhaps be less incentive to stockpile prior to the opening date. An additional advantage to this approach are that it provides a relatively regular supply for industries. However, levels of effort would be more difficult to control, and there is some potential for recruitment over-fishing with this approach.

Management models

Management models to be considered include most classic models. Models such as the Schaeffer yield model and Ricker recruitment model are not likely to be useful in the near future because of the limited data. Where available, the data serie is restricted to isolated villages and periods of only a few years (Figure 3). The Beverton-Holt yield per recruit model can be applied to the isolated villages for which data are available. However, the fishing mortality levels predicted as optimal for the village of Quintay ($F=0.4$) were much lower than the observed levels ($F=1.7$) (Geaghan and Castilla, 1987) and may not be truly optimal for this artisan fishery. The Beverton-Holt model is based on biomass, but the locos are traditionally sold as numbers of individuals, not by weight. In recent years some consideration of size and quality has been taken into account in the sale of locos, but the number of units remains the primary consideration in the sale of locos by the fishermen. This partly negates the effectiveness of the Beverton-Holt model.

A fishing mortality of 0.4, the value predicted as optimal by the Beverton-Holt model, in the village of Quintay would require only 1 or 2 boats fishing on a regular basis, a large reduction from the average of 8 prior to 1985, and much below the approximately 20 boats which are disposed to fish locos during the shortened seasons. However, it may be better for 8 or 10 artisan fishermen to make a living than for 1 or 2 be extremely successful. We suggest, therefore, that the "optimum" for this fishery may not be simply the economic optimization of yield, but rather that a larger number of fishermen given access may in fact be optimal.

Geaghan and Castilla (1986, 1987) developed a simple simulation model for 4 fishing villages in central Chile. This approach is particularly interesting, since unlike most traditional management models, it provides a day to day indication of stock levels. The model is useful in evaluating the effect of hypothetical management techniques.

Cohort analysis has also been used in several studies of the loco. Since ages are not available, the version used has been that of Jone's adaptation to use with lengths. While providing much useful information, this model is particularly dependent on the availability of a good growth model.

Another potentially useful model for loco management is Kimura's stock reduction analysis. The potential use of this model for the loco has not yet been explored in published literature.

An additional, recent development of interest is the epossibility of concessions of sections of the sea for individual management by scientific or commercial enterprises. This should be a major consideration in future management plans, since concessions cannot be included in the national quota, and if well managed could limit effort and open the way for continuous fishing, thus following the "long term opening" pattern described. A successful concession could also provide recruitment to adjacent areas. Managing a concession will require information on a small scale, both spatially and temporally. Investigating and managing agencies should be prepared to provide some assistance to concessionaires. Concessions, in turn, could become a valuable source of information and understanding of locos population dynamics, and that of other species as well.

CONCLUSIONS

Although there is considerable understanding of the behavior and growth of locos, there are numerous aspects of the early life history that have not been documented, but are important to understanding population dynamics. There is no published literature on the survival or extent of dispersion of the planktonic larval stages. The fecundity of the loco has been recently examined by Durán and Castilla (1988) but the potential of reproduction by unexploited sub-legal size classes (60 to 100 mm) to support the fishery has not been examined.

Population units of the loco have yet to be defined, and the influence of environment on growth and other life history aspects have not yet been determined. The literature shows various discrepancies in growth models and other aspects of the life history, particularly the period of copulation, formation of maicillos and egg capsule deposition. It is not clear if these differences are regional, environmental or just variation between authors and techniques.

Traditional methods of evaluating stock densities bases on catch and effort data have been extensively used. However, there is some question as to whether this use is valid, since some of the assumptions associated with these methods are not met. These questions must be addressed, not if catch per unit of effort is used, the best level of resolution of fishing grounds for the application of catch and effort has yet to be determined (regional, village or individual fishing baks).

Although some estimates of mortalities are available, a single value of natural mortality has been used for most studies and management assessments. The dependency of this value on age, and different life stages has not yet been determined.

Perhaps the most important lack of information is in the area of recruitment. The type of relationship between adult populations and recruitment is not known. The decreasing population densities represented by the declining catch per unit of effort information (Figure 3) may have a great impact on recruitment, but to date there is no information on recruitment densities.

Goals

The most immediate concern of fishery managers must be to insure continuance of the fishery, especially against recruitment failure. The establishment of refuges is one measure which may help insure against such a failure. Other immediate concerns are to optimize the yield by refining the national quota or determing an adequate period of aperture for the fishing season, and to bring some stability to a fishery which has undergone a series of changes in regulations in the last 8 years. Another short term goal should be the development of techniques for monitoring recruitment levels.

In the medium term, the concerns of management must be to refine quotas or open seasons in order to optimize the fishery at the regional level. This will allow management to take advantage of parameter estimates and stock production estimates for the appropiate sub-populations of loco. The development of a recruitment index in order to evaluate the potential for recruitment failure should be undertaken as soon as techniques for monitoring recruitment are developed.

Long term goals would include the continued refinement and optimization of the chosen management technique. This should be greatly facilitated by the development of a recruitment index and model, and the estimates of regional parameter estimates such as growth. Once the relationship between parental stock and recruitment is documented, impact of stocking and repopulation can be better assessed.

The information required to meet these goals is first, traditional fishery data, in the form of catch and effort data. This type of data should be taken continuously. In oder to obtain this data, fishery managers must regain some measure of control over fishing patterns. The present practices of apozamiento and clandestine fishing negate any attempt to obtain adequate fishery data.

Efforts must be made to develop an index of recruitment. This is necessary to develop an adequate management model and to assess the potential for restocking.

Education

Many of the existing problems in the loco fishery would be more manageable if communication with the fishermen were improved, and if they were better informed about management objectives. McHugh (in Lackey and Nielsen, 1980) discusses the resistance of fishermen to management, and the effect of competition among the fishermen. He states that "the only possible remedy for resistance to management is some form of education". Channels of communication between managers, fishermen and industry are virtually noexistent in the present loco fishery.

Competition among the loco fishermen is great, and is manifested particularly in the taking of sub-legal individuals and in apozamiento. If other fishermen take sub-legal individuals, then the individual who does not is at a decided disadvantage. The competition for sub-legal individuals occurs primarily on a village by village basis, and indeed size selection varies greatly between villages and between years. Competition to fill the quota by stockpiling, which in turn results in a shortened season and a greater need for stockpiling, works at both a local and national level. This competition is particularly fierce since a fisherman who does not stockpile is devastated by a season lasting only 6 days.

Education and communication would likely be relatively effective in the prevention of sub-legal individuals, since this involves cooperation at only a local level. With the cooperation of industry and improved enforcement, the potential for growth overfishing should be relatively easy to address.

A much more difficult problem is the elimination of apozamiento. A fishermen approaching a fishing season that will be terminated upon completion of a quota, and with the knowledge that the previous season lasted only 6 days, must stockpile in order to obtain his share of the common resource. The designation of a season, 45 or 90 days, instead of a quota, would undoubtedly help in reducing apozamiento. This would also insure managers of some useful catch and effort data if the season were longer than the two or three week period in which extensive apozamiento is likely to be practiced.

The establishment and dissemination of clear, well defined management objectives should do much to improve relations between managers and fishermen. The fishermen are entitled, for example, to know under what conditions the fishery will be closed. If the development of concessions is realized, then the need for communication will be increased as the fishermen then become the managers.

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