THE CHILEAN TURF SYSTEM: HOW IS IT PERFORMING IN THE CASE OF THE LOCO FISHERY?

Jorge González, Wolfgang Stotz, Jorge Garrido[†]*, J. M. (Lobo) Orensanz, Ana M. Parma, Carlos Tapia, and Alejandro Zuleta*

ABSTRACT

Chilean benthic fisheries involve thousands of artisanal fishers, about 50 target species (most significantly loco, *Concholepas concholepas* (Bruguière)), and a coastline spanning 38 latitudinal degrees. An overfishing crisis led to a closure of the loco fishery (1989–1992), and to the incorporation of territorial use rights in fisheries (TURFs) into fisheries legislation. Organizations of artisanal fishers are entitled to co-manage parcels of seabed with the state. We used old and new data on the loco fishery of Region IV (the cradle of the system) to investigate the performance of TURFs, which presently encompass 36% of the prime habitat that contributed close to 82% of historical yield. Abundance within TURFs and legal catch are stabilized, the fishery looks orderly, and perception of TURFs is generally positive. The system is dual, however, and at least half of the catch is illegal, originating from background areas outside the TURFs. Corrective action requires incentives that would eliminate the illegal catch, increase fishermen's participation, and provide simple feedback decision rules driven by data and more flexibility allowing fishermen to experiment and diversify activities. Attention is needed to biological processes at scales that transcend the boundaries of locally managed TURFs and to values and priorities other than biological sustainability that may be of societal significance.

Granting secure access rights to fishers is increasingly predicated as a key element for the sustainability of fisheries (U.S. Commission on Ocean Policy, 2004; Hilborn et al., 2005). In the case of benthic resources, exclusive access rights may take the form of territorial use rights in fisheries (TURFs), often allocated to communities of coastal fishers (Christy, 1982, 2000). TURFs have existed for centuries as a form of traditional tenure (Johannes, 1977) and have been institutionalized in modern Japan for the harvest of sedentary resources (Ruddle and Akimichi, 1984; Yamamoto, 1995). Although these systems are watched with interest as an alternative for the management of benthic shellfish (e.g., Prince et al., 1998), Chile has taken the lead by incorporating TURFs, locally known by the Spanish acronym AMERBs ("Áreas de Manejo y Explotación de Recursos Bentónicos"), into the Fisheries Act ("Ley General de Pesca y Acuicultura"; Montt-Vicuña et al., 1997) enacted in 1992 (Castilla and Fernández, 1998; Castilla et al., 1998; Orensanz et al., 2005). Involving tens of thousands of artisanal fishers and hundreds of communities spread along a coastline that spans 38° of latitude, this is the largest contemporary attempt to introduce a TURF system de novo, where it was not established by tradition. Formal implementation of the Chilean AMERB system started in 1997 and was reviewed by an external panel in 1999 (Orensanz et al., 2005). Although perceptions of the system have been generally positive (San Martín et al., 2003), its performance has not yet been formally evaluated.

Institutionalization of the Chilean AMERB system was triggered by a crisis in the fishery for loco (*Concholepas concholepas* (Bruguière, 1789)), a predatory snail that

† Third to seventh authors listed in alphabetical order.

superficially resembles herbivorous abalone (Stotz, 1997; Castilla and Fernández, 1998; Avilez and Jerez, 1999). Although approximately 50 benthic species (invertebrates, algae, and fishes) are harvested by Chilean artisanal fishers, loco is the most significant, and the status of the loco resource drives perceptions about performance of the management system. We focus on Region IV (one of the country's 12 administrative regions), first, because it is the cradle of the system, where empirical exploration of de facto territorial tenure and spatial management practices started (Stotz, 1997; Avilez and Jerez, 1999) and, second, because Region IV (and particularly the community of Los Vilos) has been a focal point of fishermen's activism. Fishermen's direct action there led to the lifting of a 4-yr closure in 1993.

We screened a variety of sources of information and conducted field research to construct indicators of the performance of the AMERB system with regard to biological sustainability, using the loco fishery of Region IV as a test case. Despite extensive research on loco and its fishery (including AMERBs) and long-term, detailed monitoring programs, this is the first time that a significant part of the information available is examined in an integrated context. The lessons are significant and, we believe, transcend the particular case of this fishery.

The Study System

Chile's Artisanal Fishery.—Continental Chile spans about 38° of latitude, from approximately 18°S (border with Peru) to 56°S (Cape Horn). Administratively the country is divided into 12 regions (Fig. 1); Regions I–IX correspond to the central-north coast, spread almost linearly with a north-south direction. Along this extensive coastline "caletas" and their adjacent fishing grounds form the social/geographic/ecological template of the artisanal fishery; caletas are coastal locations that serve as operational bases for local artisanal fleets (Fig. 2). In rural areas, caletas are equivalent to fishing villages; in urban areas, fishers and their families are part of larger communities (Castilla et al., 1998). In a typical caleta of central Chile, diving for shellfish coexists with long-lining for finfish, and individuals have variable levels of mobility between the two sectors; the fleet is composed of boats 7–8 m long without decks or cabins (Fig. 2). Benthic resources are harvested primarily by commercial divers, crab trapping being an occasional complement. Fishers are generally well organized; caleta-based organizations are grouped into regional federations, and these into two national confederations. A centralized agency, the Undersecretary of Fisheries ("Subsecretaría de Pesca," SUBPESCA), has authority over management of all fisheries, offshore as well as inshore. Under this umbrella, the National Fisheries Service ("Servicio Nacional de Pesca," SERNAPESCA) is in charge of enforcement and compiling landing statistics. The Institute for Fisheries Development ("Instituto de Fomento Pesquero," IFOP), a semi-governmental agency, monitors benthic fisheries under a contract to SUBPESCA.

Expansion and Collapse of the Loco Fishery.—The rise and fall of the loco fishery has been chronicled and discussed in detail by Castilla and Fernández (1998). Demand increased sharply during the late 1970s, as new markets developed in the Far East (Fig. 3). Under open access no incentives encouraged conservation. Mounting effort was countered with increasingly shorter seasons. Catches were high during the early 1980s, but sensing symptoms of overfishing, managers imposed a closure in some regions between September 1985 and May 1987 (Reyes, 1986). Fishers from

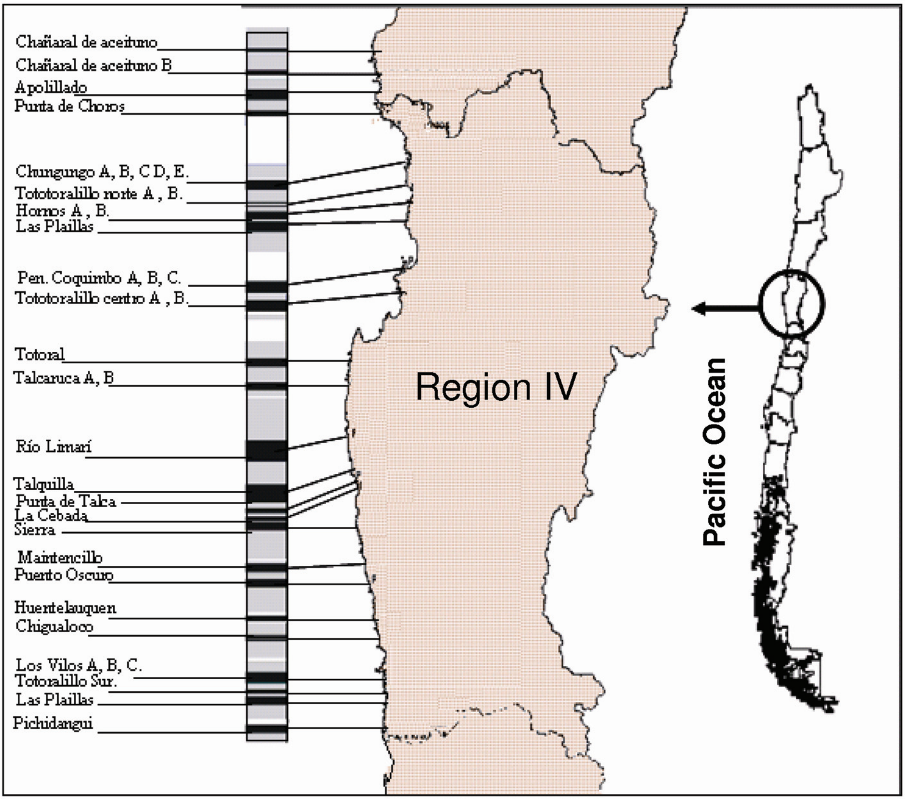

Figure 1. Right: map of Chile showing the country's 12 administrative regions; left: Region IV with indication of the caletas (local fisher communities) that hold AMERBs (areas of territorial user rights). Bar to the extreme left indicates status of segments along the coast: black, AMERBs that include loco as a target resource; gray, background segments with suitable substrate (not incorporated into AMERBs); white, segments where substrate is not suitable for loco.

traditional fishing areas in central Chile migrated in large numbers to Region X in the south, leading to what is popularly known as "la fiebre del loco" (the loco rush). The fishery resumed in 1987, but the catch dropped sharply in 1988. Because of apparent signs of depletion, the loco fishery was nominally closed during the period from August 1989 through December 1992 (Fig. 3). A main effect of that draconian measure was turning the activity illegal, with disastrous consequences for fishing communities. Illegal fishing did not stop while the fishery was closed (Reyes, 1990; González, 1994; Stotz, 1997; Darío Rivas, SUBPESCA, pers. comm.).

The fisheries act, passed in 1992, introduced the "benthic extraction regime" for resources designated as fully exploited (including loco). This regime, which was expected to solve the problems created by open access (Bernal et al., 1999, p. 130), consisted of a total allowable catch (TAC) established for each region, split into individual quotas (IQs) among registered divers. Regional TACs were established on the basis of an analytical size-based stock assessment. In retrospect, the system is generally viewed as a failure (Bacigalupo, 2000; Orensanz et al., 2005) because of inadequacies of the assessments, increasing number of registrants, illegal trade of IQs (many were assigned to inactive fishers), and, most important, lack of incentives for conservation and poor enforcement capability.

Figure 2. Artisanal boats on the beach of caleta Totoralillo Sur, Region IV, Chile.

The TURF ("AMERB") System.—Besides IQs, the fisheries act incorporated AMERBs as an instrument for the management of benthic fisheries. The first experimental area closures in Region IV were conducted in Caleta Hornos during the late 1970s (Schmiede and Castilla, 1979). Inception of the AMERB system was nurtured by several antecedents (Castilla and Defeo, 2001; Parma et al., 2003): (i) historical fishing territories that were harvested mostly by nearby caletas (e.g., fig. 3 *in* Castilla and Jerez, 1986; Payne and Castilla, 1994); (ii) experimental fishing exclosures established during the 1980s in intertidal rocky shores (Moreno et al., 1984; Castilla and Durán, 1985; Castilla and Jerez, 1986; Durán et al., 1987; Durán and Castilla, 1989; Castilla, 1994, 1999; Castilla and Fernández, 1998); (iii) exclusive harvest rights to benthic resources granted by the state in grounds adjacent to a few well-organized caletas between 1987 and 1992 (Mendoza, 1994; Castilla, 1997; Barría, 2003; Barrios, 2003), well before the formal implementation of AMERBs; (iv) organized actions by artisanal fishers of several caletas from the provinces of Choapa and Limarí (Avilez and Jerez, 1999; Avilez, 2003); and (v) informal experiments and empirical manipulative practices implemented spontaneously by fishers in some caletas from Central Chile (Stotz, 1997).

Implementation of the AMERB system started in 1997 (San Martín et al., 2003). Background fishing areas outside AMERBs remain open to all fishers registered in the region, subject to resource-specific regulations. Industrial fleets and artisanal fishers registered in other regions are excluded, and registration in the loco fishery is under a nationwide moratorium. In 1999 AMERBs coexisted with IQs (only for loco) and "open access" (benthic resources other than loco) in the background areas. A 3-yr moratorium on loco fishing outside the AMERBs was sanctioned in June 2000, putting a de facto end to the IQ system. Since then, loco fishing in Regions I–IX has been allowed only within the AMERBs.

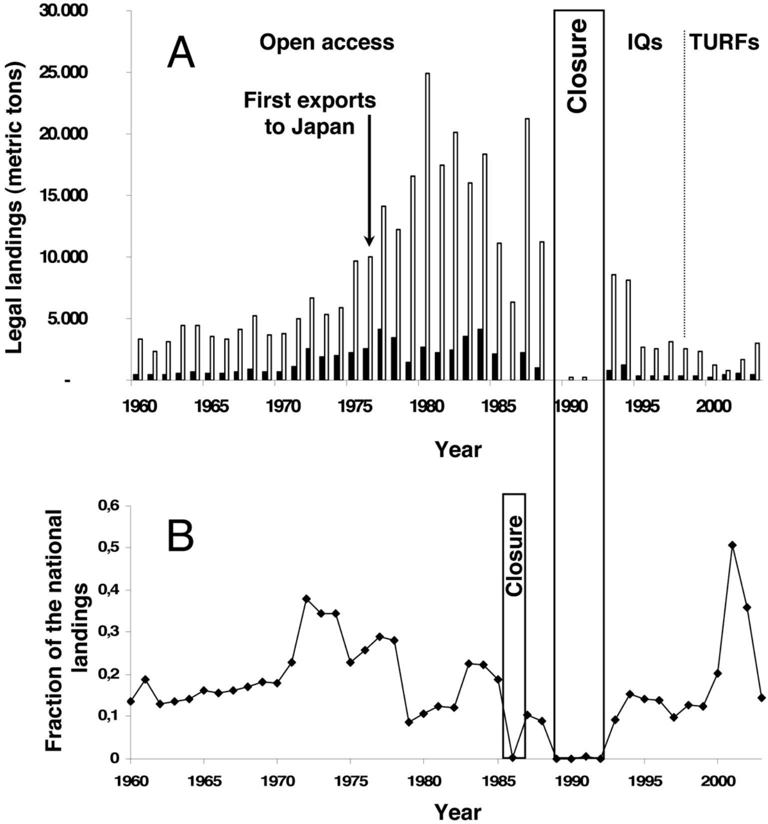

Figure 3. Legal landings of loco. A. National (black bars) and Region IV (white bars) landings, in metric tons (live weight). B. Relative contribution of Region IV to the national total. Rectangles indicate two periods of closure.

The assignment of AMERBs is a rather elaborate process (San Martín et al., 2003; Orensanz et al., 2005). Territorial rights to pre-established areas are vested in a fisher's organization upon request, provided that it produces a baseline ecological study and a 2-yr management plan (Bacigalupo, 2000; Montecinos, 2000) specifying a schedule of annual harvests and other proposed management measures. The organization is also required to produce annual follow-up reports of management performance, including trends in estimated abundance. AMERBs are assigned for 4-yr periods, renewable upon compliance with regulations. Fishers' organizations are required to hire certified consultants for the preparation of baseline studies, management plans, and follow-ups.

Methods and Sources of Information

Geographic Range.—The study area includes the seabed along the coasts of Region IV and the southern end of Region III, down to a depth of 25 m. Although the bathymetric range of distribution of loco may extend to 40 m depth (DuBois et al., 1980), fishers indicated that abundance of loco below 25 m is negligible. The study area was conceptualized as a latitudinally spread stripe including AMERBs and interspersed segments of background area. The latter are often referred to as "open access areas" or "historical areas" in Chile; both denominations are here considered misleading. Average width of the stripe between 2 and 25 m depth is 216 m; the estimated linear spread of the coastline is 316.7 km.

Spatial Partitions.—The basic spatial elements recognized in the analysis of the fishing process are the "procedencias," sites of differing extent that fishers recognize by vernacular name and use to indicate the place of origin of the catch. A total of 266 procedencias were identified from the database of the port-sampling program conducted by IFOP between 1993 and 1999 (described below).

The stripe-shaped study area was partitioned into a sequence of polygonal, discrete "cells," the minimal spatial partitions definable in terms of management and habitat suitability. Cells fall into three categories: (1) AMERBs that have loco as a target resource, (2) interspersed segments of background area that contain at least some suitable loco habitat (see below), and (3) segments without suitable habitat (e.g., extended stretches of subtidal sandy bottom associated with sandy beaches), including some AMERBs that do not have loco as a target resource. The total number of cells defined was 109, subsuming 49 AMERBs, 42 background areas with suitable habitat, and 18 areas (background or AMERBs) without suitable habitat (Fig. 1). All procedencias were located, geo-referenced by GPS, and assigned to one of the 109 cells. Cells were grouped into five "macrozones" for some of the analyses. Macrozones group strings of caletas that, according to our team's experience, have identifiable ecosystemic properties. All the geo-referenced information was incorporated into a GIS platform; the software used was Arcview. The GIS was used to estimate the extent of areas and borders, to assign procedencias to cells, etc.

Ecological Categories of Seabed.—Areas of seabed were coarsely classified into two broad categories: potentially suitable (hard substrate) and unsuitable (soft bottoms). Potentially suitable substrates include rocky bottoms, large boulders ("bolones"), and shallows; unsuitable substrates are composed of various admixtures of sand, shell hash, and mud. Following Wilson (2002), we recognized four basic benthic physiognomies within potentially suitable areas: (1) communities dominated by macroalgae (*Lessonia trabeculata* Villouta and Santelices, *Macrocystis integrifolia* Bory), (2) communities dominated by encrusting organisms (mostly crustose coralline algae), (3) communities dominated by suspensivores (mostly colonies of large barnacles, *Austromegabalanus psittacus* (Molina), and piure ascidians, *Pyura chilensis* Molina, that tend to occupy exposed rocky shallows), and (4) bleached bottoms dominated by coralline algae ("*Mesophyllum*") and grazers (mostly the black sea urchin, *Tetrapygus niger* L. Agassiz). The proportions of suitable and unsuitable area were calculated for each cell. Loco was most abundant in the assemblages dominated by suspensivores but was present also in areas where the physiognomy was dominated by encrusting algae or macroalgae; it was virtually absent from bleached substrates. Hard bottoms, with the exclusion of bleached areas, were defined as "effectively suitable."

Port Sampling.—Between 1980 and 1984 SERNAPESCA recorded total catch and effort daily at Cruz Grande, Caleta Hornos, and Coquimbo (Geaghan and Castilla, 1986, 1987). We were unable to locate the original data, but average catch per unit effort (CPUE) values were digitized from figures 1 (Cruz Grande) and 3 (Hornos) of Geaghan and Castilla (1987). Each value corresponds to the average of 10 trips. Data from Coquimbo were considered unreliable by those authors and therefore were not used in their studies.

During 1984 and 1985 a port-sampling program was conducted by IFOP in 15 caletas (Bustos, 1985, 1986). A similar program was implemented between 1993 (the year when the fishery reopened) and 1999 (last year in which fishing was allowed in background areas under the IQ regime). Port samplers, stationed during the entire length of the season, interviewed crews of all boats as they returned to the caleta. Information recorded for each trip included boat ID, number and names of divers, catch, duration, depth at fishing location, "procedencia," diving time, ex-vessel price, and expenditures (fuel, etc.). In 1993 the survey covered all the designated landing sites, aiming at 100% coverage (IFOP, 1993). Twenty sites were designated, including 14 caletas and six "authorized landing sites" (some of the latter were formally recognized as caletas in subsequent years). Between 1994 and 1999 the sites sampled were a subset of variable composition; only three caletas (Pta. Choros, Chungungo, and Hornos) were continuously sampled during that period (Barahona, 2000, and references therein). In 1999 (last year of the program) port samplers covered landings originating from both AMERBs and background areas. A sample of the catch was measured in situ. Samplers had as a goal to measure (total shell length in millimeters) a minimum number for the season (e.g., 6000 per caleta in 1993). Approximately half of the individuals measured had to be weighed (total weight in grams). When samplers were overwhelmed, they were instructed to sample the catch, attempting to maximize the number of procedencias. Landings and measurement files are linked in the database by information on the trip.

The effort units used were daily trips in the case of SERNAPESCA (1980–1984) and diving hours in the case of IFOP (from 1984 on). In order to convert data from SERNAPESCA to units used by IFOP, we examined the frequency distribution of diving hours per trip in data collected by IFOP at Caleta Hornos during the period 1993–1999. The distribution had a well-defined mode at four diving hours per trip (corresponding to trips with a single diver). Accordingly, we used a factor of 0.25 to convert CPUE data from SERNAPESCA to units used by IFOP. The operating mode of the fleet did not change substantially during the 1980s and 1990s, and data did not show any trend in diving hours per trip during the period 1993–1999. In the estimation of CPUE for Caleta Hornos, we excluded a few distant procedencias that were visited occasionally (Choro, Dama, and Pájaro Is.).

Since 1999, catches from the AMERBs have been recorded and reported to SUBPESCA by the consultants. Six of them operate in Region IV, including IFOP and Universidad Católica del Norte (UCN).

Direct Surveys of Abundance.—During the 1990s a number of studies conducted direct assessments of abundance before the AMERBs were implemented (Stotz and Pérez, 1992; Jerez, 1993; Mendoza, 1994; IFOP, 1994a,b; González et al., 1998, 1999).

After the implementation of the AMERBs (starting in 1998) surveys were conducted in the form of baseline studies and follow-ups, as described above. Sampling protocols are designed to be simple and understandable by commercial divers, who always participate in the surveys. Each baseline study and follow-up is documented in a detailed report submitted to SUBPESCA. This information was made available by SUBPESCA to Project FIP 2002-16 (González et al., 2004).

In the surveys conducted by UCN, transects perpendicular to the coastline were quasi-regularly spread over the study area at approximately 50-m intervals. Half of the transects was surveyed by divers from UCN and the other half (interspersed with the preceding) by commercial divers from the caleta. Ten stations were spread along each transect at 2-m depth intervals, down to 20 m depth. Five 1-m^2 quadrats were haphazardly allocated at each station. All locos in the quadrats were collected, labeled, measured and weighed, and released.

Surveys conducted by IFOP were based on stripes (sampling units) perpendicular to the coastline; each stripe was 100 m long and 4 m wide. The number of stripes was dictated to some extent by available logistical support and the configuration of the coast.

Typically, stripes were spread haphazardly at intervals of approximately 150 m. The diving team was always coordinated by technicians from IFOP and incorporated fishers from the local caleta. Divers swam along the stripe, counting all the individuals in sight. Sampling units were poststratified by broad habitat type: large boulders, rocky shallows, and sand. Baseline studies also included charts of bathymetry, type of bottom (IFOP uses a Questar-Tangent acoustic bottom classification system), and major benthic physiognomies (described above). Divers collected (haphazardly) up to 50 locos from each stripe; these were measured and weighed. Ancillary information recorded included local toponomy, a census of the fleet and fishers, specifics about fishers' organizations, and infrastructure. The other consultants (except UCN) follow IFOP's protocol.

Outside AMERBs, 11 cells of background area were surveyed in 2003 (Gonzalez et al., 2004). Diving transects, perpendicular to the coastline, extended between the isobaths of 2 and 20 m. Ten stations were distributed along each transect at depth intervals of 2 m. A sample of 10 1-m^2 quadrats (sampling units) was obtained at each station; quadrats were haphazardly thrown from the boat. All locos found along the transect were removed, labeled, and measured.

CPUE within the AMERBs and Experimental Calibration of CPUE.—In the case of AMERBs assessed by IFOP, CPUE was regularly recorded during supervised harvests in which monitored fishers were asked to fish within the boundaries of the AMERB as they would have done in an open-access situation. The relation between average density estimated in the baseline study and CPUE during the first subsequent harvest was investigated with data from 17 AMERBs tracked by IFOP, but these data contain little information on the pattern at low density. A complementary experiment designed to fill that gap was conducted in five background cells (González et al., 2004). CPUE (locos h^{-1}) of commercial divers and abundance were measured in the same locations and at the same time.

Interview Program.—A structured interview program was conducted in 2003 among fishers. The purpose was to gather empirical information on resource ecology and abundance, CPUE in background areas, economical indicators, and illegal catch from background areas. Interviews were conducted in seven caletas of Region III and 20 caletas of Region IV. Individuals to be interviewed (3–5 per caleta) were selected with the participation of local fishers in the locales of their organizations. We always attempted to select at least one senior diver (to get a historical perspective) and a younger one (for emphasis on the current state of the resource). Underlying the interview was a formal questionnaire, but sessions followed a loose format designed to facilitate the flow of ideas from interviewed fishers and to avoid the induction of responses. The interview was accompanied by a map of the area where fishers operate (scale 1:50,000), on which they indicated procedencias, folk toponomy, areas of mating aggregations ("maicillos") and recruitment ("maternidades") of locos, benthic assemblages, and prevalent currents. Responses from fishermen were kept confidential. Information requested included the number of divers that fish loco illegally, main fishing areas, months in which illegal fishing occurs, average diving hours per day, average CPUE (locos h^{-1}), price, average size in the catch, and primary market. A second set of questions was designed to estimate income and expenses. The difference between monthly income and expenses (always negative) was considered a proxy of the illegal catch and converted to loco units by means of price figures. The questionnaire and other details of the survey are described in detail by González et al. (2004).

Official Statistics.—Statistical information compiled by government agencies corresponds to three categories.

Catch Statistics.—SERNAPESCA compiles and reports landing statistics (expressed in live weight) by caleta, available at http://www.sernapesca.cl; hard copies of Anuario Estadístico de Pesca (annual reports) are distributed upon request.

Export Statistics.—Loco exports are reported by the national customs administration for each type of processed product (frozen, canned, refrigerated, dried) by weight (records can be purchased from the agency). These figures can be converted to number of individuals by a formula using the average yield for each product (Quintana et al., 1994) and average weight of live locos. Export statistics for Chile and Peru (the only two countries that produce loco) are available from FAO's data base (http://www.fao.org/fi/statist/statist.asp). Unfortunately, an assortment of gastropods is pooled in Chilean statistics.

Confiscation Statistics.—Intercepted deliveries of illegal catches (not accompanied by chain-of-custody paperwork) are confiscated ("decomisos"). Confiscation statistics are available from SERNAPESCA upon request.

Results

The information described above was consolidated into six basic indicators, summarized in Table 1 (together with their supporting information) and discussed below.

Table 1. Indicators of performance of the loco fishery following implementation of the territorial-user-rights (AMERB) system, together with supporting information. IFOP, Instituto de Fomento Pesquero; procedencias, sites of differing extent that fishers recognize by vernacular name and use to indicate the place of origin of the catch; SERNAPESCA, Servicio Nacional de Pesca; caletas, communities of local fishers.

Indicator	Data	Source of the data	Status of indicator before and after implementation of the AMERBs
Area and potential yield locked in the AMERBs	IFOP port-sampling program (1993 only)	IFOP Customs data base (Barahona, 2000)	Ca. 70%–80% of the relative productivity of the region is located within the AMERBs
	Georeferences of "procedencias"	González et al. (2004); http://www.fip.cl	
	GIS of the coastal zone	González et al. (2004); http://www.fip.cl	
Legal catch	Official catch statistics (SERNAPESCA)	http://www.sernapesca.cl	After lifting of the 4-yr closure (1989–1992), increased for 2 yrs, then dropped abruptly and remained constant 1995–1999; has increased steadily since AMERBs were introduced
	IFOP port-sampling program (1993 only)	IFOP Customs data base (Barahona, 2000)	
Illegal catch	Chilean customs administration records (combined with legal-catch statistics)	Customs data base (available to IFOP); Quintana et al. (1994)	Estimated to be ca. 50% of the total catch
	Official export statistics, Chile and Peru	http://www.fao.org/fi/statist/statist.asp	
	Official landing statistics, Peru	http://www.imarpe.gob.pe	
	Confiscation statistics, SERNAPESCA	Available from SERNAPESCA upon request	
Catch per unit effort	Port sampling, selected caletas: SERNAPESCA (1980–1984)	Geaghan and Castilla (1986, 1987)	After lifting of the 4-yr closure, increased for 2 yrs, then dropped, reaching a historical low in 1999; increased steadily after implementation of the AMERBs
	IFOP (1984–1985)	Bustos (1985, 1986)	
	Port sampling, IFOP, all landing sites (1993)	IFOP Customs data base (Barahona, 2000)	
	Port sampling, IFOP, selected caletas (1994–1999)	IFOP Customs data base (Barahona, 2000)	
	Monitored fishing, only in AMERBs where IFOP is the consultant (after 1999)	González et al. (2004); http://www.fip.cl	
Abundance within the AMERBS (after 1999)	Direct diving surveys of abundance (transects, stripes, quadrats; after 1998)	Baselines and follow-ups submitted by consultants to SUBPESCA (González et al., 2004)	Increased ca. 5-fold between 1998 and 2000, then remained stable
Abundance in background areas	Interview program, all caletas (2003) Direct survey of 11 coastal segments (2003)	González et al. (2004); http://www.fip.cl González et al. (2004); http://www.fip.cl	4–5 times lower than within AMERBs. Background areas harbor ca. 20% of the legal-size stock but yield no less than 50% of the catch, composed mostly of locos of sublegal size.

Area and Potential Yield Located in the AMERBs.—The estimated extent of habitat suitable for loco was 12,816 ha, of which approximately one third (36%; 4618 ha) is located within AMERBs and the rest (64%, 8198 ha) in background areas (Table 2).

We explored concentration of yield using "rarefaction" or concentration curves. Only data from 1993 were used, because in that year (i) the fishery had opened after a closure of 4 yrs, (ii) landings were monitored in all the caletas (100% coverage was available), and (iii) fishers were free to move around the region and to fish where they wished. The distribution of yield during that year is a reasonable index of relative productivity. Procedencias were ranked by catch and their order (highest to lowest) was plotted against the corresponding percent cumulative catch. The resulting curve shows high concentration: 75% of the catch originated from 21.3% of the procedencias (Fig. 4).

Once the implementation of the AMERBs started, the number of AMERBs with suitable substrate for loco increased quasi-linearly during the 5-yr period 1999–2003 (from 4 to 49), and so did the extent of seabed locked into the AMERBs (from 500 to 4500 ha; Fig. 5A). If cells are weighted by the yield of 1993, the picture is very different (Fig. 5B). Potential yield locked in the AMERBs grew fast at the beginning of the period but approached a plateau afterwards. The implication is that, as expected, the most productive areas were claimed first after implementation of the AMERBs started. Of 226 procedencias harvested in 1993, 71.2% fall into the AMERB cells that were implemented by 2003; those procedencias contributed 81.7% of the 1993 catch.

Port-sampling data from 1993 were also used to explore the extent and alongshore distribution of the areas harvested by fishers from each caleta before implementation of the AMERBs and the degree of overlap between those areas. Data from 1994 to 1999 could not be used to that end because coverage of the caletas was incomplete. Use made by fishers from different caletas of a given procedencia was weighted by effort allocated (number of trips to the procedencia). Locations harvested by fishers from adjacent caletas did overlap, but the effective overlap was minimal, as illustrated in Figure 6 for Macrozone 10, even though that macrozone was the most intensely fished during that period.

Legal Catch.—Region IV has contributed a significant fraction of the national loco annual reported landings (Fig. 3B), 17% (on average) over the last 45 yrs. The absolute maximum was ca. 4000 mt in 1977 and 1984 (Fig. 3A). The relative contribution declined between 1972 and 1988, partly because of a decline in abundance and partly because of increasing reported landings in Region X, fostered to a large extent by a southward migration of fishers from Region IV. Region IV reported landings rose to prominence during the early 2000s because of that region's lead in the implementation of the AMERB system. In 2001 it contributed ca. 50% of the national legal landings (Fig. 3B). Reported landings in the postclosure years have been modest by preclosure standards; the maximum was 1240 mt in 1994. Legal landings have steadily increased since the implementation of the AMERB system.

Illegal Catch.—Products of illegal fishing have three main destinations: (i) local markets, (ii) processing for export, and (iii) illegal exports to Peru, where they are processed and exported as Peruvian loco. Illegal exports soared during the 4-yr closure, when routes were established and perfected (Reyes, 1991). Confiscations reached three million locos in 1990 alone (roughly equivalent to 600 mt). Enforcement agents estimated that the annual illegal catch during that period was about

Table 2. Area (in ha) of the subtidal stripe (2–25 m depth; illustrated in Figure 1) and length of the coastline (in meters) that corresponded to AMERBs and background areas in 2004. Cells, polygonal, discrete segments of the coastal stripe (minimal spatial partitions definable in terms of management and habitat suitability); macrozones, larger linear segments into which cells were grouped.

		Macrozone					
	Type of cell	6	7	8	9	10	Total
Number of cells	Background areas with habitat suitable for loco	6	8	4	14	10	42
	AMERBs that have loco as a target resource	4	11	5	14	15	49
	Areas without suitable loco habitat (AMERB or background cells)	3	5	3	2	5	18
	Total	13	24	12	30	30	109
Habitat suitable for loco (ha)	Background areas with habitat suitable for loco	1,157	1,319	763	3,544	1,415	8,198
	AMERBs that have loco as a target resource	818	483	129	1,654	1,535	4,618
	Total	1,975	1,802	892	5,197	2,950	12,816
Coastline (m)	Background areas with habitat suitable for loco	29,327	35,374	17,422	103,270	33,426	218,819
	AMERBs that have loco as a target resource	6,060	21,623	4,903	44,304	20,968	97,858
	Total	35,387	56,997	22,325	147,574	54,394	316,677

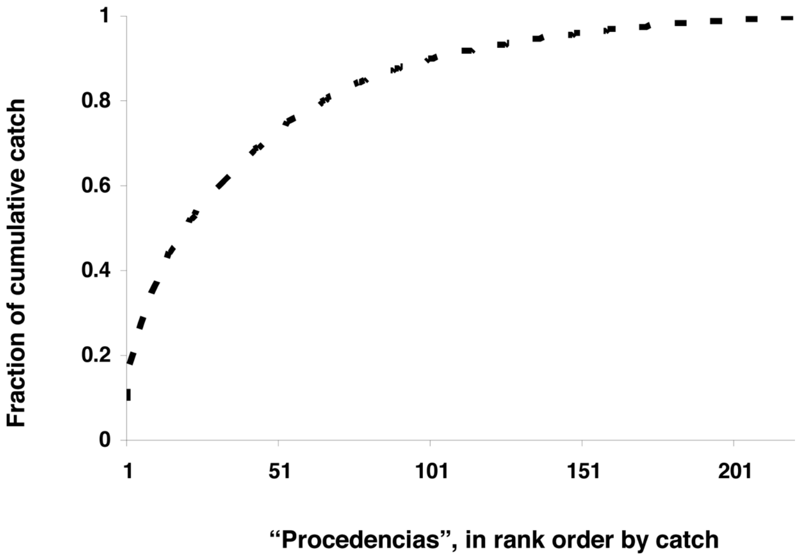

Figure 4. Concentration of the catch by "procedencias" (sites of differing extent that fishers recognize by vernacular name and use to indicate the place of origin of the catch) before implementation of the AMERB system, based on port sampling during 1993.

4000–5000 mt. Smuggling of locos to Peru is well acknowledged and often recorded in the press (see for example coverage in *El Mercurio*, Santiago, 13 June 2004, reporting illegal traffic of Chilean loco to Tacna, Peru). Landings from Peru are modest (IMARPE, http://www.imarpe.gob.pe), but statistics compiled by FAO show significant exports of Peruvian origin suddenly starting in 1990, just after the beginning of the Chilean closure (Fig. 7). If all Peruvian exports were of Chilean origin, this illegal source would bring illegal exports for the period 1993–1999 up to approximately 48% of the landings (excluding illegal catch consumed domestically).

Comparison of catch and export statistics gives an idea of the illegal export-oriented catch at the scale of the whole country (export statistics are not split by region of origin). The difference between SERNAPESCA landing statistics (converted from weight to numbers) and export statistics (estimated numbers) is an indicator of exports of illegal origin. Results for the period 1993–1999 indicate that 26% of the exports were of illegal origin (Fig. 7). The figure would be somewhat higher if legal domestic consumption were deducted, although it is considered negligible.

Cumulative confiscations for the period 1993–1998 amounted to 7.5% of the quota. Enforcement agents consulted "guesstimate" that approximately 5%–10% of the illegal catch is intercepted, implying that illegal and legal catches were close to each other.

Since implementation of the AMERB system, illegal catch has had several origins: (i) fishing in background areas (presumably the most important), (ii) poaching from AMERBs of other caletas, and (iii) undeclared fishing within fishers' own AMERBs. In 2003 annual illegal catch was calculated for each cell of background area on the basis of information from the interview program (number of divers that fish illegally, days of operation, average daily catch, and average number of diving hours). The calculated illegal catch for that year was 2.8 million locos, roughly equivalent to the legal catch during the same period. Average CPUE indicated for background areas by

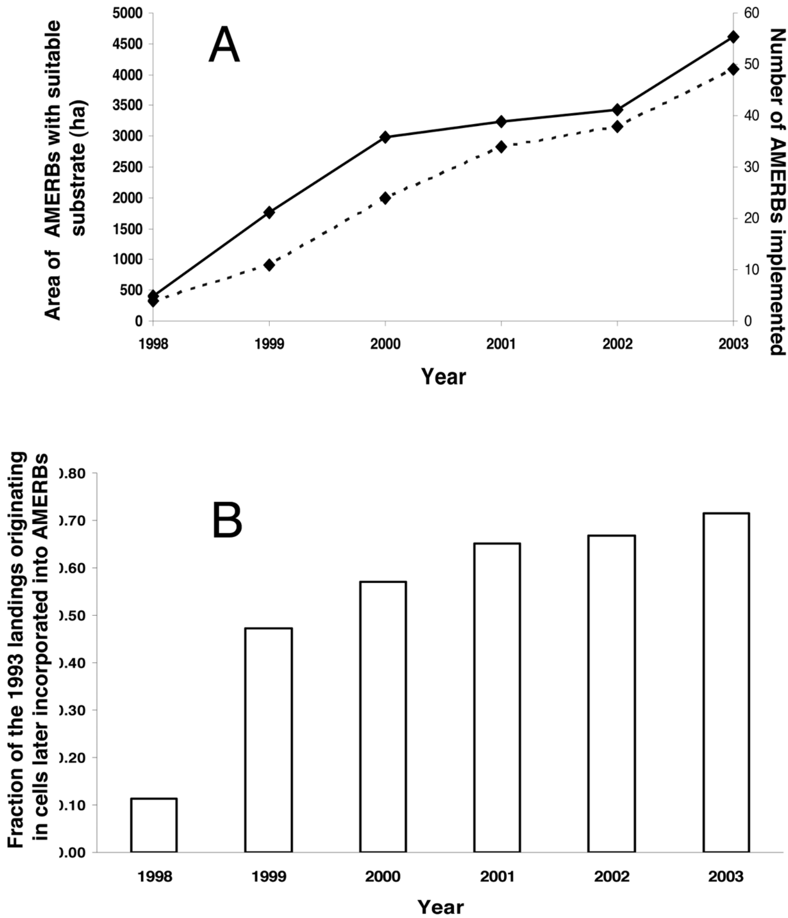

Figure 5. Expansion of the AMERB system after 1998. A. Number (dashed line) and total area (in ha, solid line) of incorporated AMERBs. B. Productivity locked into the AMERBs, expressed as a fraction of the catch in 1993.

interviewed fishers was 28 locos h^{-1}; in the particular case of Caleta Hornos, it was 15 locos h^{-1}. Fishers indicated that the average size of individuals caught illegally is 7.7 cm (range 4.5–9 cm), well below the legal size of 10 cm (shell maximum length).

Catch per Unit Effort.—The caleta sampled most consistently over the years was Hornos, where catch and effort data were recorded by SERNAPESCA from January 1982 through September 1984, by IFOP between June 1984 and September 1985, and again by IFOP during the 1993–1999 period (Fig. 8A). The series can be extended back to 1980 with data from nearby Cruz Grande, which was surveyed between February 1980 and June 1983. Average CPUE fluctuated around 300 locos h^{-1} between January 1980 and August 1982, then suddenly dropped to ca. 200 locos h^{-1} in both Cruz Grande and Hornos and continued declining gradually through 1985. When IFOP started monitoring in June 1984, recorded CPUE was 67 locos h^{-1} in Caleta Hornos and 87 locos h^{-1} in nearby Cruz Grande. The pattern shown by combined figures from SERNAPESCA (1980–1984) and IFOP (1984–1985) is very consistent (Fig. 8A). When the fishery closed in September 1985, average CPUE had dropped to 27

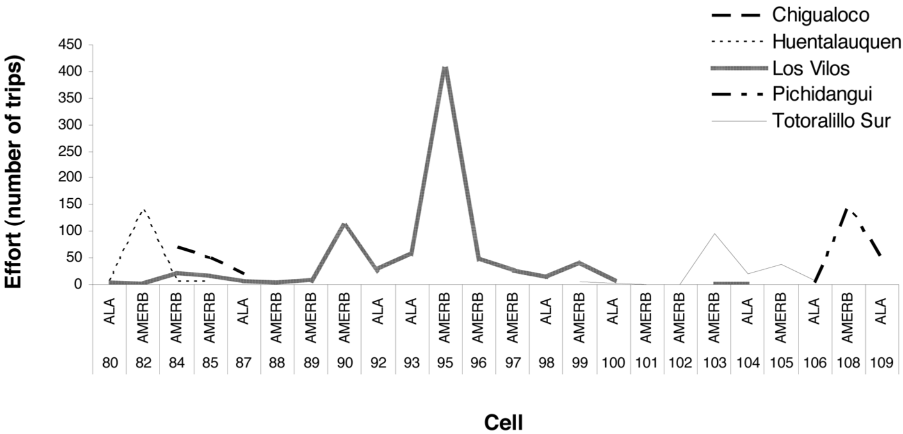

Figure 6. Areas of influence of caletas from Macrozone 10. Segments (cells) are numbered consecutively from north (left) to south (right). ALAs, background cells with suitable substrate for loco; cells without suitable habitat were omitted.

locos h^{-1} in Cruz Grande and 32 locos h^{-1} in Hornos, both very close to the regional average of 31 locos h^{-1}. The fishery remained closed through May 1987 and was not monitored when it reopened in 1987–1988. No data are available for the 4-yr period 1989–1992, when the fishery was nominally closed, so no indices of abundance are available for the eventful 6-yr period 1987–1992. When the fishery was opened during a 4-d window in 1993 (19–22 January) average CPUE was 113 locos h^{-1}; during the second opening in 1993 (26 July–2 August) and the single opening in 1994 (22–31 August) CPUEs were 284 and 241 locos h^{-1}, respectively. Average CPUE dropped five-fold between 1994 and 1995 (4 September–27 October), to 53 locos h^{-1}. It remained low in subsequent years, reaching 10 locos h^{-1} during the opening of 1999 (3 September–30 November), an all-time historical low.

The pattern illustrated with Caleta Hornos is representative of what happened in Region IV at multiple spatial scales (caletas, macrozones, whole region); the data show

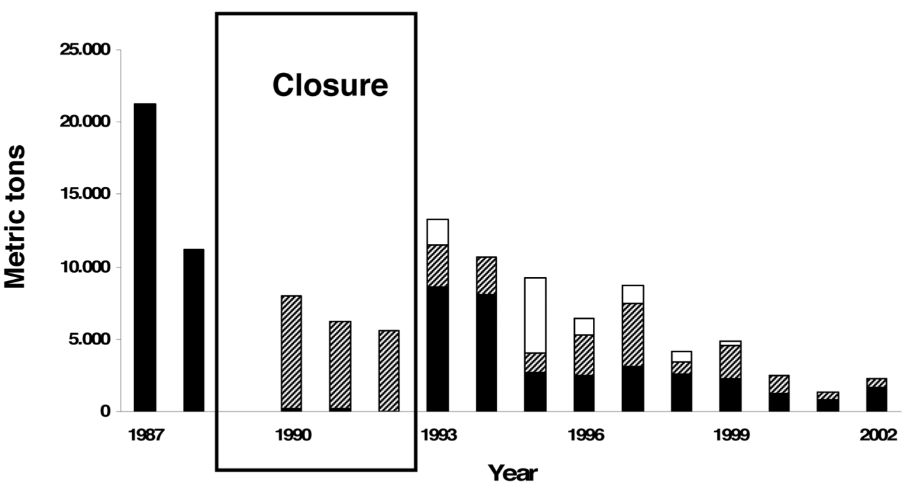

Figure 7. Probable illegal catch after 1989. Dark segments, legal catch; light segments, exports of illegal origin; shaded segments, exports from Peru.

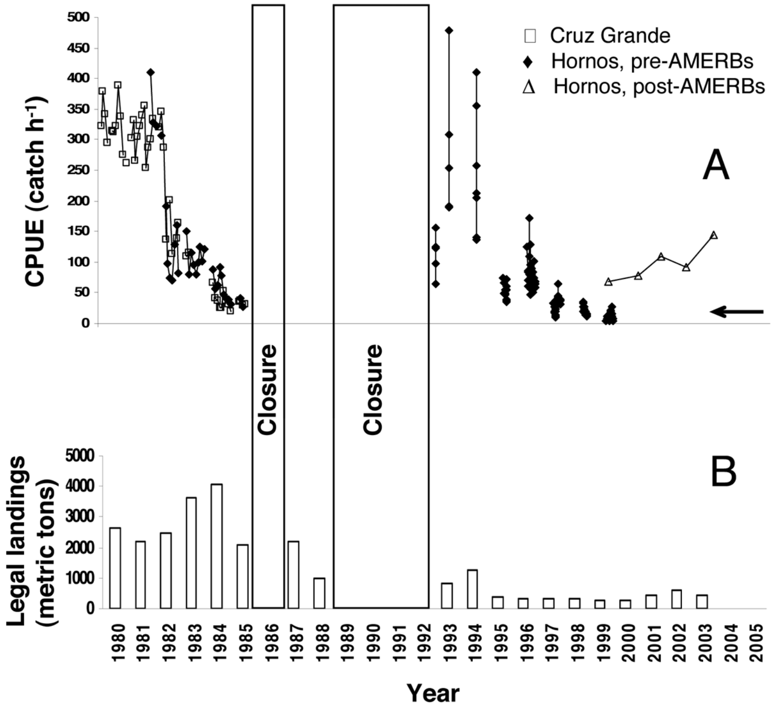

Figure 8. Caleta Hornos. A. Historical trends in catch per unit effort (CPUE), reconstructed from various sources. The arrow points to the CPUE in background adjacent areas estimated from interviews in 2003. B. Legal catch from Region IV.

remarkable geographic coherence. The average pattern of 15 caletas port-sampled by IFOP between June 1984 and September 1985 is very consistent (Fig. 9).

Limited spatial resolution of the total catch reported by SERNAPESCA and partial coverage by IFOP's port-sampling program in 1994–1999 create problems for combining data and for analyses at the caleta level, particularly for Macrozones 6–8. We decided to focus on Macrozone 10 for two reasons: (1) catches recorded by SERNAPESCA for that macrozone probably originated there, and (2) the artisanal fishery of Los Vilos has a long tradition and is considered the cradle of commercial diving in Region IV. During the first 1993 opening, a consistent 2–3-fold drop in CPUE was evident in all the macrozones (Fig. 10A), from approximately 150–250 locos h^{-1} to 50–100 locos h^{-1}. When the fishery reopened on 26 July, CPUE was back at the early January level (or even higher), then declined 2–3-fold over the 8 d of the opening, to approximately 100 locos h^{-1} (Fig. 10A). On average, trends were similar at the finer scale of the caletas from Macrozone 10 (Fig. 10B). A consistent, region-wide 3–4-fold drop in CPUE occurred between 1993 and 1998 (Fig. 11A). This general pattern was observed in all the macrozones and in the caletas from Macrozone 10 (Fig. 11B). As is the case for pre-closure years, the pattern observed in Caleta Hornos is very consistent with that of the rest of the region.

In the case of Caleta Hornos, average annual CPUE (recorded during the harvests) increased steadily between 1999 and 2003, from 69 to 145 locos h^{-1} (Fig. 8), accompanying a corresponding increase in the abundance of legal-size locos available in the AMERB, from 94,000 (baseline study of 1999) to 300,000 (follow-ups of 2002 and

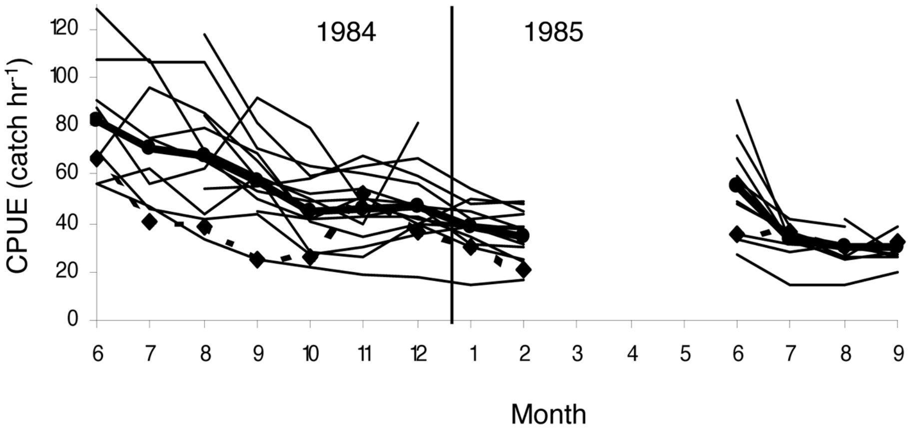

Figure 9. CPUE in 15 caletas of Region IV where a port-sampling program was conducted during 1984–1985. Thin solid lines, individual caletas; heavy solid line, regional average; dashed line, Caleta Hornos.

2003) individuals. Maximum CPUE levels in 2003 were comparable to average CPUE in the spring of 1982 (after CPUE abruptly dropped) and during the first opening of 1993 but were still much lower than during 1980–early 1982, the second opening of 1993, and the opening of 1994. In 1999, when IQs and AMERBs coexisted, CPUE within the AMERB (70 locos h^{-1}) was seven times higher than that in the background areas where fishermen completed their IQs (Fig. 8).

Abundance within the AMERBs (after 1999).—The information provided by studies conducted during the 1990s (listed above), before the implementation of the AMERB system, proved too heterogeneous and incompletely specified. Its use in an integrated context would require substantial research and location of original data sets (provided that they still exist in some format). This effort was beyond the scope of our study. Once implementation of the AMERBs started, a general pattern was observed: density increased sharply between the baseline study and the first follow-up, then stabilized. This pattern is apparent both at the level of the individual AMERBs (Fig. 12B) and of aggregated abundance at the macrozone level (Fig. 12A), as well as for data compiled by different consultants.

Abundance in Background Areas.—Density estimated directly in 11 background cells ranged from 0.015 to 0.097 locos m^{-2} (mean 0.04 m^{-2}). Abundance in background cells was also calculated indirectly, from a combination of CPUE information from the interview program and the relation between CPUE and density observed experimentally. Following Harley et al. (2001), we fitted a power function, $CPUE = \alpha D^{\beta}$, to the experimental data set (described above); estimated parameter values were $\alpha = 124.42$, $\beta = 0.2836$ (Fig. 13). Estimated density was higher in AMERBs (0.45 locos m^{-2} on average) than in background cells (0.10 locos m^{-2} on average) along the entire coast of Region IV (Fig. 14). Estimates of density and area of suitable substrate were combined for calculation of abundance in background cells. Although these estimates are very rough, they give an idea of the status of the stock in relative terms. Although background areas spread over 64% of the suitable habitat, in 2003 they harbored only 28% of the population and 20% of the legal-size stock, yet up to 63% of the catch, composed mostly of individuals of sublegal size, originated from background areas.

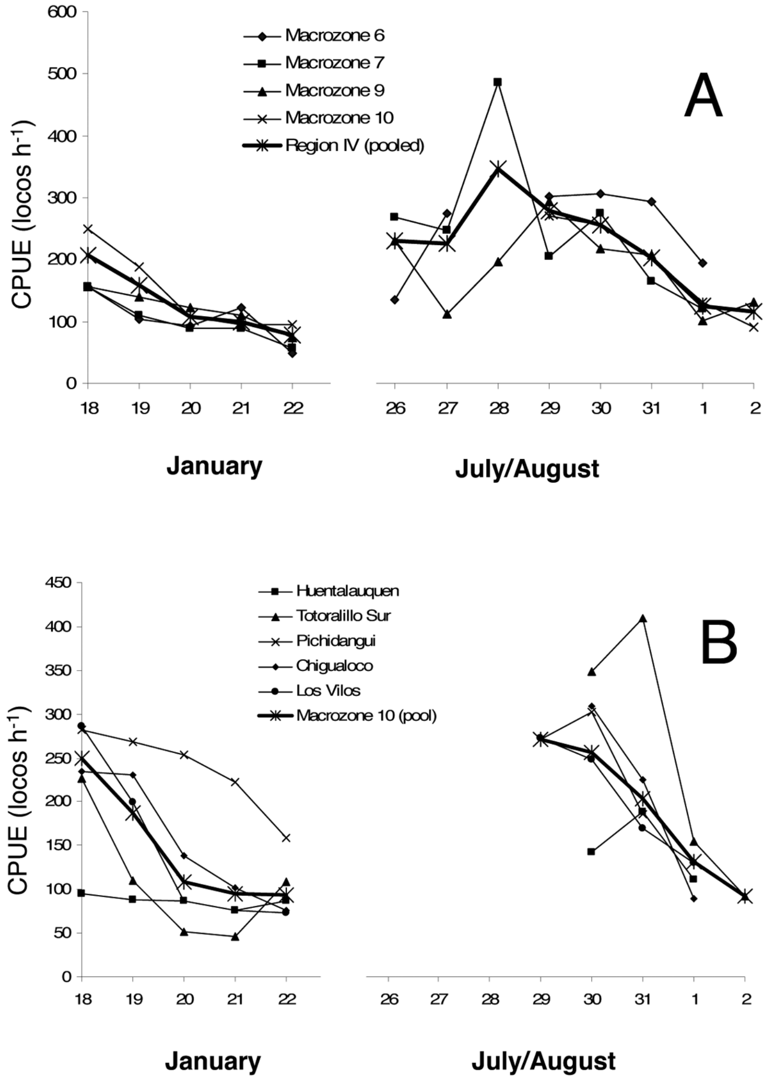

Figure 10. Within-year trends in CPUE after the fishery was opened for two short periods in 1993. A. Macrozone averages; thick solid line indicates regional grand mean. B. Average for caletas of Macrozone 10; thick solid line indicates grand mean for the macrozone.

Discussion and Conclusions

AMERBs and the Biological Sustainability of the Loco Fishery.—Although the literature on loco and its fishery is rather extensive, fishery data are fragmentary and dispersed in many repositories, are often difficult to retrieve, and had been never integrated before. We emphasized indicators that, at least for a subset of locations, could be informative across transitions through very different management regimes, for example CPUE. Our results on the relation between CPUE and density indicate nonlinearity and a tendency to hyperstability that may be related to the behavior of loco, serial search-depletion in the fishing process, or both (Orensanz et al., 1998).

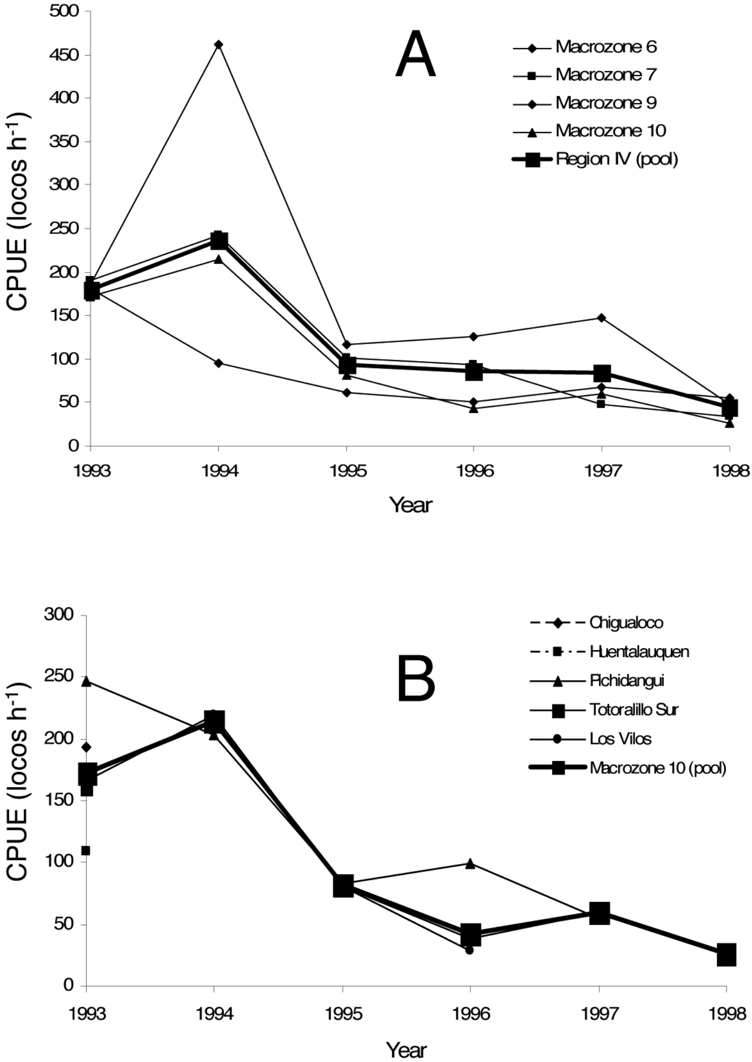

Figure 11. Trends in average annual CPUE after the fishery was opened, 1993–1999. A. Macrozone averages; thick solid line indicates regional grand mean. B. Average for caletas of macrozone 10; thick solid line indicates grand mean for the macrozone.

Locos tend to hide in crevices and under rocks, and only the visible fraction of the stock is vulnerable to divers. After the vulnerable fraction on a patch of rocky bottom is depleted, some individuals will eventually move from cryptic to exposed locations, renewing the stock that is locally available. As a result, repeated visits are necessary before depletion becomes evident; i.e., the catch rate is hyperstable. On the other hand, in the short run, if the rate of removal exceeds the rate of replenishment of high-density patches, then hyperdepletion may dominate. The latter apparently arises during the rapid fall of CPUE within each season (Fig. 10). A similar type of dynamics is captured by the "foraging arena" model of Walters and Juanes (1993). Our results on the relation between CPUE and abundance must be considered very preliminary, particularly for higher values of abundance. Despite acknowledged lim-

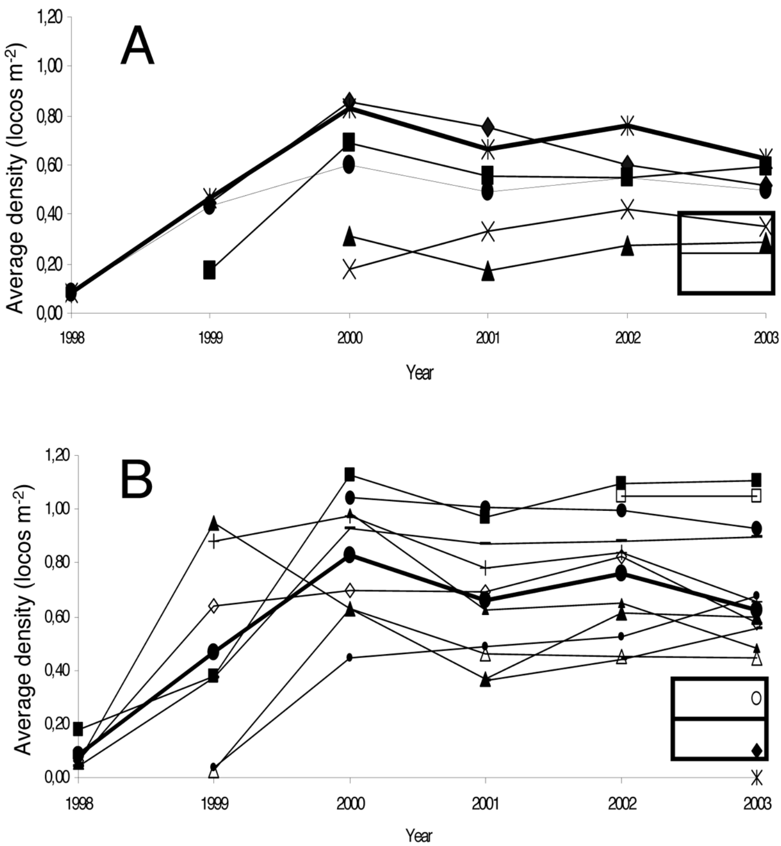

Figure 12. Density of locos in the AMERBs after implementation of the system. A. Macrozone averages; thick solid line indicates regional grand mean. B. Average for caletas (AMERBs) of macrozone 10; thick solid line indicates grand mean for the macrozone. Macrozones and AMERBs are not identified by name because of confidentiality restrictions. Rectangles indicate the range and average estimated for background areas on the basis of the 2003 interview program.

itations, historical trends in CPUE are very informative and consistent at various scales of spatial aggregation of the data (Figs. 8–11) and at different time scales, from long-term (Figs. 8, 11) to intra-season (Fig. 9) to 1-wk openings (Fig. 10). A tendency toward equalization of CPUE over the scale of the region is consistent with fishers' moving around to maximize their catch rate (i.e., with the ideal free distribution; Prince and Hilborn, 1998). Consistency came as a surprise to us for several reasons: (i) the well-known limitations of CPUE as an index of abundance in the case of benthic fisheries, prone to extreme hyperstability (Orensanz et al., 1998); (ii) collection of the port-sampling data under at least three different institutional arrangements over two decades, with prolonged interruptions; and (iii) the possible significant, subjective component of port-sampling interview data (in this case mostly in the reporting of effort). Cross-scale consistency supports the use of individual caletas for which long-term series of data are available (e.g., Hornos) as a proxy for a macrozone or even the entire Region IV.

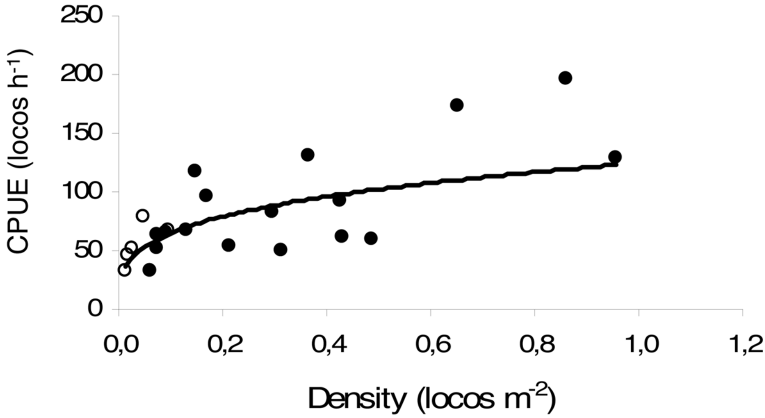

Figure 13. Relation between CPUE and density in cells surveyed by Instituto de Fomento Pesquero (IFOP). Fill circles, density observed in baseline studies, plotted against CPUE during the subsequent harvest event; open circles, experiments conducted in background areas.

The decline of loco stocks that led to a countrywide closure during 1989–1992, well illustrated by Caleta Hornos, has dominated the discussion about difficulties and options in the management of this resource but conceals the fishery's three declines of comparable proportions, at least in Region IV and perhaps in other regions as well: that in 1982–1985, which ended in the 1986 closure of the fishery in several regions (including Region IV); that in 1986–1987, which led to the 4-yr closure; and that in 1994–1999, whose end coincided with the implementation of the AMERB system.

The first and third episodes are well captured by historical trends in CPUE at diverse geographical scales, from region to procedencia. Unfortunately, the second episode and the ensuing 4-yr closure were not accompanied by a monitoring program; nothing was documented (either directly or indirectly) during this significant period. The lifting of the closure was the result of political pressure from organized fishers empirically familiar with conditions and was supported by a few scientists. Science played a small role in this momentous transition. This information vacuum leaves many questions unanswered; overfishing of loco was never conclusively demonstrated. Recovery of areas that were effectively closed to harvesting during the

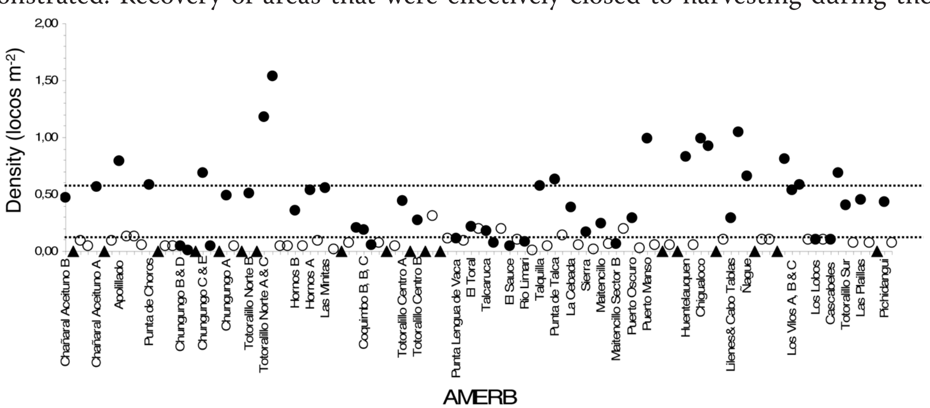

Figure 14. Estimated loco density in AMERBs (solid circles) and background cells with suitable habitat (open circles) in 2003. Density is always zero in cells without suitable substrate (triangles). Cells are arranged from north (left) to south (right). Dotted lines indicate average density in AMERBs (0.45 locos m^{-2}) and background areas (0.10 locos m^{-2}).

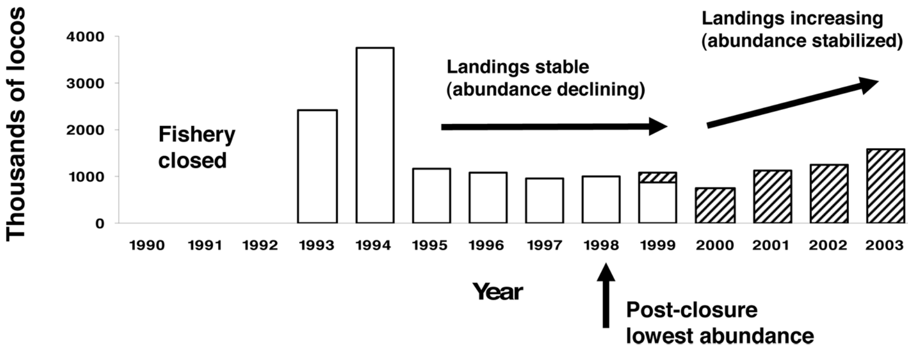

Figure 15. Legal landings of loco in Region IV after the closure was lifted in 1993 and status of the stock. Open bars, landings under the IQ regime; hatched bars, landings from AMERBs. Notice that the two legal regimes coexisted only in 1999.

countrywide closure was too fast (0.5–3 yrs; Castilla, 1997; Stotz, 1997) to reflect recovery from recruitment overfishing. This and other pieces of information can be interpreted as evidence of immigration from inaccessible harvest refuges that may have effectively prevented recruitment overfishing (Stotz, 1997).

After the fishery reopened, CPUE in Hornos was at a level comparable to that of the mid-1980s, but the regional legal catch that led to a similar rate of CPUE decline was comparatively low (Fig. 8). Possible causes of this mismatch may include underreporting of landings in 1993–1994 or a leveling off of CPUE at very high loco abundance. Enforcement agents and others agree that illegal catch was at a minimum in 1993–1994, mostly because of the strictures that accompanied the lifting of the closure, but illegal catches outside the openings are likely and seem to be consistent with sizeable Peruvian exports in 1993–1994. Leveling off of CPUE, on the other hand, is also plausible given that even prime loco habitat has a local carrying capacity. Predatory loco are known to move away from patches where prey items have been depleted. Unfortunately this behavior is difficult to document because of the extreme scarcity of sampling surveys during the 1980s. CPUE peaked during the second opening of 1993 (26 July–2 August, Fig. 10) and remained high during 1994 (Fig. 11). This transient peak in abundance was apparently the result of a strong year class that entered the fishery in 1993, somehow hastening the expectations of full recovery (W. Stotz, pers. obs.).

By 1999, at the time of the transition from IQs to AMERBs, the stock was apparently at its all-time historical low; locos thrived only in the areas that had been unofficially protected by organized fishermen. This point was clearly made by fishermen at the time and is patent in the CPUE trend (Figs. 8, 11). During the IQ regime (1993–1999) legal landings remained stable while abundance (as indicated by CPUE) plummeted to a historical low level; after the implementation of the AMERBs, abundance first recovered and now appears to remain stable, although legal landings are increasing steadily (Fig. 15). That information must now be integrated into a dynamic model that also includes size data (which we did not consider). This challenge, the subject of currently ongoing research, is a daunting one because modeling must capture the spatial heterogeneity of the relevant processes, although the spatial resolution of the data is very uneven.

One significant aspect to consider in the transition from open access and IQs to TURFs is changes in the spatial allocation of effort, an issue that underlies debates about the historical legitimacy of territorial use privileges. Although the assumption seems reasonable that before the implementation of AMERBs fishermen harvested grounds near their caletas, the extent to which fishing grounds were exploited primarily by fishers from nearby caletas, leading to broad overlap of their fishing areas, was unclear. The only antecedent was provided by Castilla and Jerez (1986, fig. 3), who illustrated pictorially the extent and overlap of areas fished by three adjacent caletas in Region V, suggesting moderate or no overlap among them. Analysis of the 1993 port-sampling data indicates that although overlap occurred between the areas harvested by caletas of Region IV, fleets allocated most of their effort to neighboring fishing grounds. Effective overlap (weighted by effort allocation) was minimal. This finding has important implications: AMERBs correspond largely to the fishing grounds harvested by fishermen from each caleta before AMERBs were implemented. In other words, this result confirms that the formal partition of fishing grounds that resulted from the introduction of the AMERB system matches the informal geographic pattern of effort allocation by caletas during pre-AMERB years.

AMERBs were conceived during the late 1980s and early 1990s as a way to overcome a critical situation. Although their implementation was delayed a few years, it happened just in time to prevent a new lingering crisis, when the IQ system had failed and the stock was at a historical low. Not surprisingly, therefore, politicians, managers, most scientists, leaders of fishermen organizations, the press, and the public have, on balance, a positive perception of the system. Managers (SUBPESCA) can show a successful fishery (mostly in the case of loco and limpets), yielding a product of comparatively good quality at a convenient price (Bacigalupo, 2000). They also enjoy the prestige attached to the implementation of a creative solution. Enforcement (SERNAPESCA) is made easier, and the fishery (mostly in the case of loco) appears orderly and compliant with the regulatory framework, effectively contributing to local economies through taxes. Fishers can sell in the legal market and receive a good price (Avilez, 2003). Locos are "stored" in the AMERBs until sales are arranged (Orensanz et al., 2005); in the past the catch was sold "on the beach," and individual fishers were unable to make convenient deals. Consultants found new opportunities, often by tapping into government subsidies to the implementation process. Scientists see the opportunity to test paradigms of fisheries management, like the merits (or lack of them) of right-based options. Most importantly, the practical impossibility of enforcing any kind of regulation in a small-scale fishery where landings take place in remote locations over thousands of kilometers of coastline was addressed by granting of secure access rights to fishers' organizations, providing them incentives to protect their resources themselves. Fishers' organizations self-impose strict regulations and severe penalties for transgressors, and they make a significant investment in the vigilance of their AMERBs. Positive feedback exists between the establishment of a TURF and a fishers' organization (Payne and Castilla, 1994; Stotz, 1997), a significant advantage in its own right (Avilez, 2003; Barría, 2003; Barrios, 2003).

Expectations placed on the AMERB system may be excessive, however, entailing the risk of frustration on the side of users and managers. One issue that is not sufficiently appreciated is that this is, de facto, a dual management system. AMERBs coexist with rampant illegal fishing in background areas and to some extent even within the AMERBs. All the available pieces of information, although fragmentary, indicate that illegal catch is at least 50% of the total catch. The fraction would increase if the illegal catch consumed domestically (which cannot be estimated) were factored in. This figure is consistent with the 60% illegal catch estimated by some scientists and managers familiar with the system, partly from data on fishermen's income and expenditures (UCN, 2002; González et al., 2004). Fishers have no incentive not to fish all year round in background areas and even argue that this is a legitimate practice because in the old days they were free to fish wherever they wished during protracted seasons. The illegal catch does not comply with legal size, seasons, or other regulations.

Direct and indirect estimates indicate that CPUE is very low (0.05–0.10 locos m^{-2}) in background areas, 5–10 times lower than in AMERBs not just as a result of illegal fishing: locations of AMERBs were chosen to capture the most productive procedencias. Of 226 procedencias harvested in 1993, 71% fall into the AMERBs that were implemented by 2003. Although AMERBs extend over approximately one-third of the substrate suitable for loco, procedencias within them accounted for 82% of the catches in 1993, when fishers were free to move around. This high figure may overestimate the relative productivity of areas within AMERBs, if high-density grounds were subject to higher exploitation rates during the short openings in 1993. Notwithstanding, in this dual management system, a large fraction of the productivity is clearly locked into the component where rights-based management is at work, a positive situation from the viewpoint of biological sustainability.

Beyond Biological Sustainability.—Whereas the 1988–1992 closure was a desperate attempt to prevent overfishing, the subsequent institutionalization and implementation of the AMERBs attempted to solve the structural aspects of management. In a sense, AMERBs were not a choice; they became inevitable. So far biological sustainability (particularly in the loco fishery) has been, legitimately, the primary subject of concern, but management must attend to other considerations, like economical sustainability. Fishers will tend to their AMERBs only if these contribute significantly to their income; costs (vigilance, taxes, etc.) must be lower than benefits, and economical and ecological risks are present as well. Most prominent failures occurred, not surprisingly, in AMERBs whose targets were highly variable stocks, like machas (*Mesodesma donacium* (Lamarck), a beach clam) and scallops (*Argopecten purpuratus* Lamarck), which are strongly affected by El Niño events (Stotz and González, 1997; Wolff and Mendo, 2000). Markets are also uncertain. For example, some in central Chile fear that product from Region X (once AMERBs are also implemented there) will bring prices down, compromising the economy of loco-dependent communities. Another threat to economical sustainability is ill-conceived credit allocations by poorly informed banks, which have left disastrous sequels in other artisanal fisheries. Some Chilean banks take consultant reports about stock status in the AMERBs as a guarantee to grant credit to fishermens' organizations, not fully understanding the associated risks. Under pressure, fishermen may choose to empty their AMERBs rather than face the consequences of defaulting on debts. In the old days fishers coped with uncertainty by migrating between regions, tracking opportunities created by localized pulses of recruitment. Within the context defined by the fisheries act (regional registration), however, migrations are no longer legal. Fishers are forced to survive good and bad years in their caletas, depending on their AMERBs and nearby fishing grounds. Under those circumstances the most obvious prescription is active risk management (Hilborn et al., 2001), mostly in the form of diversification of the productive activities of fishing communities, something that is taking place in some communities, conditioned by specific opportunities available. Complementary activities include the harvest of nontarget resources, enhancement, small-scale aquaculture, traditional tourism (including restaurant concessions), and ecotourism.

Some sectors of Chilean society emphasize values other than biological or economical sustainability, and some of those values may conflict with the AMERB system as it is today. Some examples: (1) Social equity issues have become very significant, as fishers that did not jump into it in time were left out of the system, and some caletas received (because of their geographic location) a better lot than others. (2) Ecological integrity, as some ecologists and conservationists see the expansion of the AMERB system, as well as many management actions within the AMERBs, as a threat to biodiversity. (3) Cultural identity, which many fear was lost in the transition from freely migrating fishers to relative sedentarism.

In our opinion, as experienced practitioners and actors in the implementation of the AMERB system, and considering the problems encountered in the process, the system must be rethought. Some requirements that are closely intertwined were envisioned early by Stotz (1997) and later advanced by an external panel cosponsored by SUBPESCA and IFOP, just at the beginning of the implementation process (Orensanz et al., 2005; the consensus report of the panel is available from the corresponding author upon request). The most significant problems are:

The Persistence of a Dual Management System.—As a member of the international panel put it in 1999, the coexistence of divergent management regimes is a recipe for disaster. One suggestion advanced by the panel was to expand the AMERBs to cover all the suitable areas, but this action would generate conflict with other users, aggravate equity issues, and increase the cost of AMERB maintenance (area-based taxes, surveys and vigilance), aggravated because AMERBs would expand over areas of low productivity. This issue clearly requires serious discussion with participation of various stakeholders.

Lack of Flexibility and Little Local Control over Management Actions.—Management actions subject to little control include manipulative experimentation, small-scale aquaculture, and enhancement. Diversification should be encouraged, and use of alternative and non-target resources should be promoted. Fortunately, both SUBPESCA (management) and SERNAPESCA (enforcement) have applied regulations with much flexibility, facilitating adjustments in the system.

Little "Effective" Participation by Fishers in Monitoring and Management.—True participatory management requires changes in all the actors. Fishers should be more active in the decision process and less subservient to consultants. For these changes to be possible, fishers must understand the dynamics of the resources that they harvest. They must be able to establish a dialogue with consultants and managers and not just be handymen for survey activities, while assisting their advisors with questionable conviction. In order to become effective stewards, fishers must participate in the identification of the problems, design and conduct surveys and experiments, gather the information, and understand the results. Incentives for corresponding changes in the attitude of managers, scientists, and consultants are needed as well. The complexity of the implementation (baseline studies, management plans, follow-ups) makes the system dependent on state subsidies and forces an obligatory marriage of fishers and consultants. Although this situation created a business opportunity for the latter, participation by fishers in the management process is limited and mediated by the consultant. A revamped system should provide incentives for new forms of technical/scientific assistance, perhaps modeled after Prince's (2003) concept of a "barefoot ecologist."

No Clear Decision Rules to Adjust Harvest Regulations in Response to Monitoring Indices.—Feedback decision rules should be clear, simple, and driven by data. Models could be used to evaluate decision rules given what is known about the system, but they should not be part of the regular management cycle.

Finally, two management issues transcend the local scale of individual fishermen organizations and their AMERBs. First is the inevitably large scale of biological processes mediated by the dispersal of larvae (Orensanz et al., 2005). AMERBs are not independent of each other or of background areas: action taken in one place will affect others. This problem requires an integrative vision from managers and discussion among stakeholders (including fishermen) at the regional scale. Marine reserves are an indispensable component of any integrated system (Castilla, 2000; Moreno, 2003). The second issue, closely related to the first, is the need to integrate AMERBs into a coherent policy for the management of the coastal zone that aims to compromise between diverse, often conflicting, societal values and priorities.

Acknowledgements

Most of the information presented in this contribution resulted from a project supported by the Fondo de Investigaciones Pesqueras, Chile (Project FIP N° 2002-16, 2003-2004), entitled "Bases Biológicas para la Evaluación y Manejo de Metapoblaciones de Loco en las III y IV Regiones (Chile)." We acknowledge the staff of IFOP (Valparaíso and Coquimbo) and Universidad Católica del Norte (Coquimbo) for their support. In particular, we appreciate help from N. Barahona with data from IFOP's port-sampling program, C. Cortés for managing the data for the project, C. Guevara for GIS support, and A. Wilson for comments on community ecology. J. Valero (Seattle) helped with EDA. Three thorough anonymous reviews, careful editorial work by A. B. Thistle, and comments by A. Cinti on the first draft greatly enhanced the clarity and organization of the text. Participation by AP and LO was facilitated by Pew Fellowships in Marine Conservation and CONICET (Argentina); those authors both value insightful discussions with Profs. J. C. Castilla (Santiago) and C. Moreno (Valdivia). We extend our very special appreciation to the fishermen of Region IV and their leaders, without whose collaboration this study would have been infeasible and senseless.

Literature Cited

Avilez, O. 2003. Experiencia en el manejo y explotación de las áreas de manejo de recursos bentónicos en las caletas artesanales de la IV Región. Pages 1–6 *in* G. A. San Martín, A. Pinto, M. Montecinos, A. González, and J. A. Guerra, eds. Taller de áreas de manejo—experiencias y proyecciones. Unidad de Areas de Manejo, Departamento de Pesquerías, Subsecretaría de Pesca, Valparaíso.

______ and G. Jerez. 1999. Gestión sustentable de recursos marinos bentónicos en caletas de la IV Región. Ambiente y Desarrollo (Chile) 15: 6–10.

Bacigalupo, F. H. 2000. Pesquerías concesionadas a pescadores artesanales en Chile. Pages 32–47 *in* FAO, Taller sobre manejo y asignación de recursos pesqueros a pescadores artesanales en América Latina, Valparaíso. FAO/Universidad Católica de Valparaíso, Santiago.

Barahona, N. (comp.). 2000. Seguimiento del estado de situación de las principales pesquerías nacionales, 1999—Tomo IV (recurso loco). Subsecretaría de Pesca, IFOP, informe final, Valparaíso. 64 p.

Barría, R. 2003. Experiencias y proyecciones en áreas de manejo del sindicato de pescadores artesanales de Maitencillo. Pages 15–20 *in* G. A. San Martín, A. Pinto, M. Montecinos, A. González, and J. A. Guerra, eds. Taller de áreas de manejo—experiencias y proyecciones. Unidad de Areas de Manejo, Departamento de Pesquerías, Subsecretaría de Pesca, Valparaíso.

Barrios, R. 2003. Experiencia de Quintay en el manejo de recursos bentónicos en las areas de manejo. Pages 11–14 *in* G. A. San Martín, A. Pinto, M. Montecinos, A. González, and J. A. Guerra, eds. Taller de áreas de manejo—experiencias y proyecciones. Unidad de Areas de Manejo, Departamento de Pesquerías, Subsecretaría de Pesca, Valparaíso.

Bernal, P. A., D. Oliva, B. Aliaga, and C. Morales. 1999. New regulations in Chilean fisheries and aquaculture: ITQ's and territorial use rights. Ocean Coastal Manage. 42: 119–142.

Bustos, E., ed. 1985. Diagnóstico de las principales pesquerías nacionales bentónicas III, IV y X Región. I. Estado de situación del recurso. Informe técnico IFOP, Santiago. 122 p.

________. 1986. Diagnóstico de las principales pesquerías nacionales bentónicas. III–IV y X región—1985. IFOP AP 86/55, Santiago. 309 p.

Castilla, J. C. 1994. The Chilean small-scale benthic shellfisheries and the institutionalisation of new management practices. Ecol. Int. Bull. 21: 47–63.

________. 1997. The sustainable use of marine coastal resources in Chile: co-management and the artisanal fishing communities. Pages 138–147 *in* Science for sustainable development in Latin America and the Caribbean. Third World Academy of Sciences, 6th General Conference, Rio de Janeiro.

________. 1999. Coastal marine communities: trends and perspectives from human-exclusion experiments. Trends Ecol. Evol. 14: 280–283.

________. 2000. Roles of experimental marine ecology in coastal management and conservation. J. Exp. Mar. Biol. Ecol. 250: 3–21.

________ and O. Defeo. 2001. Latin American benthic shellfisheries: emphasis on co-management and experimental practices. Rev. Fish Biol. Fish. 11: 1–30.

________ and L. Durán. 1985. Human exclusion from the rocky intertidal zone in Central Chile: the effects on *Concholepas concholepas* (Gastropoda). Oikos 45: 391–399.

________ and M. Fernández. 1998. Small-scale benthic fisheries in Chile: on co-management and sustainable use of benthic invertebrates. Ecol. Appl. 8 (Suppl.): S124–S132.

________ and G. Jerez. 1986. Artisanal fishery and development of a data base for managing the loco, *Concholepas concholepas*, resource in Chile. Can. Spec. Publ. Fish. Aquat. Sci. 92: 133–139.

________, P. Manríquez, J. Alvarado, A. Rosson, C. Pino, C. Espoz, R. Soto, D. Oliva, and O. Defeo. 1998. Artisanal "caletas" as units of production and co-managers of benthic invertebrates in Chile. Can. Spec. Publ. Fish. Aquat. Sci. 125: 407–413.

Christy, F. T., Jr. 1982. Territorial use rights in marine fisheries—definitions and conditions. FAO Fish. Tech. Pap. 227. 10 p.

____________. 2000. Common property rights: an alternative to ITQs. Pages 118–135 *in* R. Shotton, ed. Use of property rights in fisheries management. Proc. FishRights99 Conference, FAO Fish. Tech. Pap. 404/1.

DuBois, R., J. C. Castilla, and R. Cacciolatto. 1980. Sublittoral observations of behaviour in the Chilean "loco" *Concholepas concholepas* (Mollusca: Gastropoda: Muricidae). Veliger 23: 83–92.

Durán, L. and J. C. Castilla. 1989. Variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. Mar. Biol. 103: 555–562.

______, J. C. Castilla, and D. Oliva. 1987. Intensity of human predation on rocky shores at Las Cruces in central Chile. Environ. Conserv. 14: 143–149.

Geaghan, J. P. and J. C. Castilla. 1986. Use of catch and effort data for parameter estimates for the loco (*Concholepas concholepas*) fishery of central Chile. Can. Spec. Publ. Fish. Aquat. Sci. 92: 168–174.

________ and __________. 1987. Population dynamics of the loco (*Concholepas concholepas*) fishery in central Chile. Invest. Pesq. (Chile) 34: 21–31.

González, J., J. Garrido, G. Jerez, A. Wilson, E. Figueroa, C. Toledo, C. Cortés, and A. Olguín. 1999. Estudio piloto ecológico y socio-económico en áreas potenciales de reserva marina en la III y IV Regiones. IFOP, Project FIP No 97-45, final report, Valparaíso. 189 p. Available at: http://www.fip.cl.

________, A. Olguín, J. Garrido, C. Cortés, C. Guevara, A. Irarrázabal, C. Toledo, G. Jerez, H. Miranda, E. Figueroa, V. Catasti, A. Wilson, W. Valdivia, and C. Romero. 1998. Investigación y análisis bioeconómico en áreas de manejo de la IV Región. IFOP, Fondo Nacional de Desarrollo Regional (FNDR), Valparaíso. 152 p.

________, C. Tapia, A. Wilson, W. Stotz, J. M. Orensanz, A. M. Parma, J. Valero, M. Catrilao, and J. Garrido. 2004. Bases biológicas para la evaluación y manejo de metapoblaciones de loco en las III y IV Regiones. IFOP (Chile). IFOP, Project FIP No 2002-16, final report, Valparaíso. 101 p. Available at: http://www.fip.cl.

Harley, S. J., R. A. Myers, and A. Dunn. 2001. Is catch-per-unit-effort proportional to abundance? Can. J. Fish. Aquat. Sci. 58: 1760–1772.

Hilborn, R., J. -J. Maguire, A. M. Parma, and A. A. Rosenberg. 2001. The precautionary approach and risk management. Can they increase the probability of success in fishery management? Can. J. Fish. Aquat. Sci. 58: 99–107.

________, J. M. Orensanz, and A. M. Parma. 2005. Institutions, incentives and the future of fisheries. Proc. R. Soc. Lond. B Biol. Sci. 360: 45–57.

IFOP (Instituto de Fomento Pesquero). 1993. Investigación monitoreo pesquería del recurso loco Zona Centro Norte 93; Regiones I a VIII. Informe IFOP-SUBPESCA, Santiago. 33 p.

________. 1994a. Diagnóstico, evaluación y manejo de las principales pesquerías bentónicas de la IV Región. Project SERPLAC-IFOP, final report, 2 vols, Coquimbo. 308 p.

________. 1994b. Investigación, evaluación y manejo de recursos bentónicos de la IV Región. Project CORFO-IFOP, Coquimbo. 51 p.

Jerez, G. 1993. Plan de explotación del recurso loco *Concholepas concholepas* de la provincia del Choapa y Limarí, IV Región. Instituto de Fomento Pesquero, Santiago. 84 p.

Johannes, R. E. 1977. Traditional law of the sea in Micronesia. Micronesica 13: 121–127.

Mendoza, O. 1994. Evaluación y manejo de recursos bentónicos IV Región. Instituto de Fomento Pesquero, FIP, final report, Santiago. 86 p. Available at: http://www.fip.cl.

Montecinos, C. M. 2000. Las áreas de manejo y explotación de recursos bentónicos: genesis, desarrollo, implementación e implicancias para la conservación de los recursos bentónicos de Chile. Tesis de Grado, Universidad Austral de Chile, Valdivia. 123 p.

Montt-Vicuña, S., E. Guerra-Salinas, and S. Montt-Oyarzún. 1997. Compilación de regulaciones pesqueras extractivas vigentes actualizado al 5 de febrero de 1997. Montt, Iruarrizaga y Cia. S.A., Abogados, Publ. Santiago. 506 p.

Moreno, C. A. 2003. Manejo de recursos costeros: la necesidad de áreas marinas protegidas del tipo reserves y/o parques marinos. Pages 71–82 *in* G. A. San Martín, A. Pinto, M. Montecinos, A. González, and J. A. Guerra, eds. Taller de áreas de manejo—experiencias y proyecciones. Unidad de Áreas de Manejo, Departamento de Pesquerías, Subsecretaría de Pesca, Valparaíso.

____________, J. P. Sutherland, and H. F. Jara. 1984. Man as a predator in the intertidal zone of southern Chile. Oikos 42: 155–160.

Orensanz, J. M., A. M. Parma, and M. A. Hall. 1998 The analysis of concentration and crowding in shellfish research. Can. Spec. Publ. Fish. Aquat. Sci. 125: 143–157.

_____________, __________, G. Jerez, N. Barahona, M. Montecinos, and I. Elías. 2005. What are the key elements for the sustainability of "S-fisheries"? Insights from South America. Bull. Mar. Sci. 76: 527–556.

Parma, A. M., J. M. Orensanz, I. Elías, and G. Jerez. 2003. Diving for shellfish and data: incentives for the participation of fishers in the monitoring and management of artisanal fisheries around southern South America. Pages 8–31 *in* S. J. Newman, D. J. Gaughan, G.

Jackson, M. C. Mackie, B. Molony, J. St John, and P. Kailola, eds. Towards sustainability of data limited multi-sector fisheries. Western Australia Department of Fisheries, Fisheries Occasional Publications No. 5, Perth.

Payne, H. E. and J. C. Castilla. 1994. Socio-biological assessment of common property resource management: small-scale fishing unions in central Chile. Out of the Shell 4: 10–14.

Prince J. D. 2003. The barefoot ecologist goes fishing. Fish Fish. 4: 359–371.

________ and R. Hilborn. 1998. Concentration profiles and invertebrate fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 125: 187–196.

______, C. Walters, R. Ruiz-Avila, and P. Sluczanowski. 1998. Territorial user's rights and the Australian abalone (*Haliotis* sp.) fishery. Can. Spec. Publ. Fish. Aquat. Sci. 125: 367–375.

Quintana, M., A. Ferman, S. Pino, and M. J. Badilla. 1994. Adecuamiento de la industria exportadora ante nuevos requerimientos de exportación. Instituto de Fomento Pesquero, internal report. Project CORFO. 71 p.

Reyes, F. E. 1986. ¿Que pasó con el loco? Crónica de un colapso anunciado. Chile Pesquero (June): 27–32.

________. 1990. Pesca clandestina y contrabando industrial de locos. Chile Pesquero 56: 45–49.

________. 1991. La veda del loco en punto muerto. Chile Pesquero 62: 37–40.

Ruddle, K. and T. Akimichi (eds.). 1984. Maritime institutions in the western Pacific. National Museum of Ethnology, Osaka. 329 p.

San Martín, G. A., A. Pinto, M. Montecinos, A. González, and J. A. Guerra (eds.). 2003. Taller de áreas de manejo—experiencias y proyecciones. Unidad de Areas de Manejo, Departamento de Pesquerías, Subsecretaría de Pesca, Valparaíso. 120 p.

Schmiede, P. and J. C. Castilla. 1979. Estudio del recurso *Concholepas concholepas* (loco) en la IV Región de Chile. Convenio SERPLAC (IV Región)-Pontificia Universidad Católica de Chile, final report, Santiago. 215 p.

Stotz, W. 1997. Las áreas de manejo en la Ley de Pesca y Acuicultura: primeras experiencias y evaluación de la utilidad de esta herramienta para el recurso loco. Estud. Oceanol. (Chile) 16: 67–86.

_______ and S. A. González. 1997. Abundance, growth, and production of the sea scallop *Argopecten purpuratus* (Lamarck 1819): bases for sustainable exploitation of natural scallop beds in north-central Chile. Fish. Res. (Amst.) 32: 173–183.

_______ and E. Pérez. 1992. Crecimiento y productividad del loco *Concholepas concholepas* (Bruguière, 1789) como estimador de la capacidad de carga en areas de manejo. Invest. Pesq. (Chile) 37: 13–22.

UCN (Universidad Católica del Norte, Coquimbo, Chile). 2002. Programa territorial integrado—Desarrollo productivo subsector pesca artesanal de la región de Coquimbo. Grupo de Ecología y Manejo (Dept. Marine Biology) and School of Commercial Engineering, final report, Coquimbo. 37 p.

U.S. Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century. Final report. U.S. Commission on Ocean Policy, Washington DC. Available at: http://purl.access.gpo.gov/GPO/LPS59977.

Yamamoto, T. 1995. Development of a community-based fishery management system in Japan. Mar. Resour. Econ. 10: 21–34.

Walters, C. J. and F. Juanes. 1993. Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taken by juvenile fishes. Can. J. Fish. Aquat. Sci. 50: 2058–2070.

Wilson, A. 2002. Estudios de situación base y seguimientos en áreas de manejo: marco conceptual e importancia de los estudios realizados en comunidades bentónicas. Thesis, Universidad Católica del Norte, Coquimbo. 44 p.

Wolff, M. and J. Mendo. 2000. Management of the Peruvian bay scallop (*Argopecten purpuratus*) metapopulation with regard to environmental change. Aquat. Conserv. Mar. Freshw. Ecosyst. 10: 117–126.

Addresses: (J.G., J.G., C.T.) *Instituto de Fomento Pesquero, Dr. Marín 340, Coquimbo, Chile.* (W.S.) *Grupo de Ecología y Manejo de Recursos, Departamento de Biología Marina, Universidad Católica del Norte, Casilla 117, Coquimbo, Chile.* (A.P., J,M.O.) *Centro Nacional Patagónico, 9120 Puerto Madryn, Argentina.* (A.Z.) *CEPES, Universidad Austral, Valdivia, Chile.* Corresponding author: (J.M.O.) *e-mail: <lobo@cenpat.edu.ar>.*