# IMPACT OF THE DISCHARGE OF BRINE ON BENTHIC COMMUNITIES: CASE STUDY OF LA CHIMBA DESALINATING PLANT, CHILE

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## Abstract

In their production process, desalination plants generate a waste consisting of seawater with a double concentration of salts, called brine, which must be disposed of in a receiving body for its subsequent dilution. Normally this receiving body is the marine environment, where an increase in salinity is produced in the area immediately surrounding the discharge sector.

This paper shows the results obtained from the environmental studies performed in the marine environment of La Chimba desalination plant located in Antofagasta, Chile, during its operation, which dates from 2003, focusing on a study performed in 2010.

The results obtained in the detailed study of benthic communities in 2010 reveal that the variation in the salinity as a result of the brine discharge has caused the creation of a new ecosystem, in which a greater variety of species and a greater number of specimens are observed.

In addition to the study performed in 2010, environmental vigilance plans to take monthly measurements of the salinity of the environment, and annual studies of benthic communities have been carried out.

The methodology used for the study involves the periodic analysis of samples of salinity in the area immediately surrounding the discharge and the qualitative and quantitative analysis of benthic organisms in the zone.

Comparing the results of the study made in 2012 and the monitoring reported in the study from 2010, the presence of an ecosystem in the discharge sector is maintained, with the predominant species being *Aulacomya ater* (mussels), making up a bank in the area.

## I. INTRODUCTION

La Chimba desalination plant, located in the city of Antofagasta in northern Chile, has a capacity of 600 litres per second, involving the production of about 670 litres per second of brine that is discharged into the sea through an outlet 240 meters long, at a depth of 15 meters. This discharge causes variations in salinity in the immediate surroundings, modifying the natural conditions of the marine environment.

In May (autumn), 2010, a detailed qualitative and quantitative study was performed on the benthic communities in the sector where the brine from the Plant is discharged, by taking samples and data from 50 stations spread out in the area of study.

A comparison of the results with follow-up plans on the benthic flora and fauna previously performed in the area (2002, 2005 and 2008), enabled determining that there is an increase in the taxa recorded in the area, in addition to an increase in the biomass in the discharge zone, mainly as a result of the settlement of a bank of "cholgas", mussels (*Aulacomya ater*), which also involves the proliferation of their depredatory species.

In 2012 (summer), a new study was made of the macro-benthic communities, in which the predominance of the Mollusca group could be seen, both in terms of abundance and as a biomass, and highlighting the species aulacomya ater, which formed a bank in the area of the study.

Contrasting the results obtained in 2010 and 2012, the following can be pointed out: The presence of *Aulacomya ater* remains as the main resource, forming a bank in the area, as well as the coexistence of predators such as echinoderms (especially starfish) and molluscs such as *Thais chocolate* ("locate").

It should be mentioned that the characterisation of the brine is monthly done in order to comply with the Chilean environmental norms, established in Supreme Decree N° 90, which establishes the emission norms for the control of contaminants associated with the discharge of liquid waste to seawater and inland surface waters. This characterisation is shown in Table 1.

In turn, a characterisation of seawater is also shown in Table 2.

| Parameter | Unit | MLA | Brine sample |
|---|---|---|---|
| Arsenic | mg/l | 0.5 | < 0.001 |
| Chloride | mg/l | - | 31,387 |
| Copper | mg/l | 3.0 | 0.32 |
| Detergent (SAAM) | mg/l | 15.0 | 0.20 |
| Tin | mg/l | 1.0 | < 0.50 |
| Fluoride | mg/l | 6.0 | 1.40 |
| Iron | mg/l | - | 0.82 |
| Magnesium | mg/l | - | 3,108 |
| Manganese | mg/l | 4.0 | 0.13 |
| Sulfate | mg/l | - | 5,655 |

**Table 1:** characterisation of brine from the La Chimba desalination plant (MLA = Maximum Limit Allowed).

| Parameter | Unit | MLA | Seawater sample |
|---|---|---|---|
| Oils and fats | mg/l | 20.0 | < 10 |
| Arsenic | mg/l | 0.2 | < 0.001 |
| Boron | mg/l | - | 2.81 |
| Cadmiun | mg/l | 0.02 | < 1 |
| Phenolic compounds | mg/l | - | 0.017 |
| Chrome | mg/l | 2.5 | < 2.5 |
| Hexavalent chrome | mg/l | 0.2 | < 0.05 |
| $BOD_5$ (20°C) | mg/l | 60.0 | < 2 |
| Detergent (SAAM) | mg/l | 10.0 | < 0.1 |
| Chemical oxygen demand | mg/l | - | 9 |
| Total hydrocarbons | mg/l | 10.0 | < 10 |
| Mercury | mg/l | 0.005 | < 0.0005 |
| Kjeldahl nitrogen | mg/l | 50.0 | 0.7 |
| Lead | mg/l | 0.2 | < 2.5 |
| Selenium | mg/l | 0.01 | < 0.001 |
| Chloride | mg/l | - | 19,126 |
| Total suspended solids | mg/l | 100.0 | 6 |

**Table 2**: characterisation of seawater (MLA = Maximum Limit Allowed).

## II. STUDY OF BENTHIC COMMUNITIES

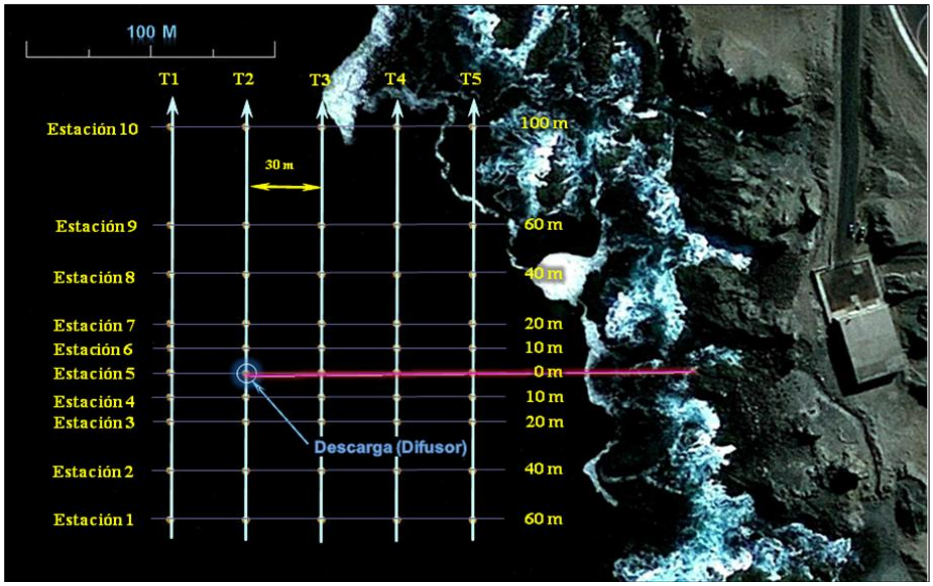
The objective of the study of the benthic communities in the sector where water is discharged from La Chimba desalination plant is to:

- Determine the status of the sub-tidal benthic communities in the brine discharge area.
- Verify the effect the discharge has on the pattern of distribution of the biota.

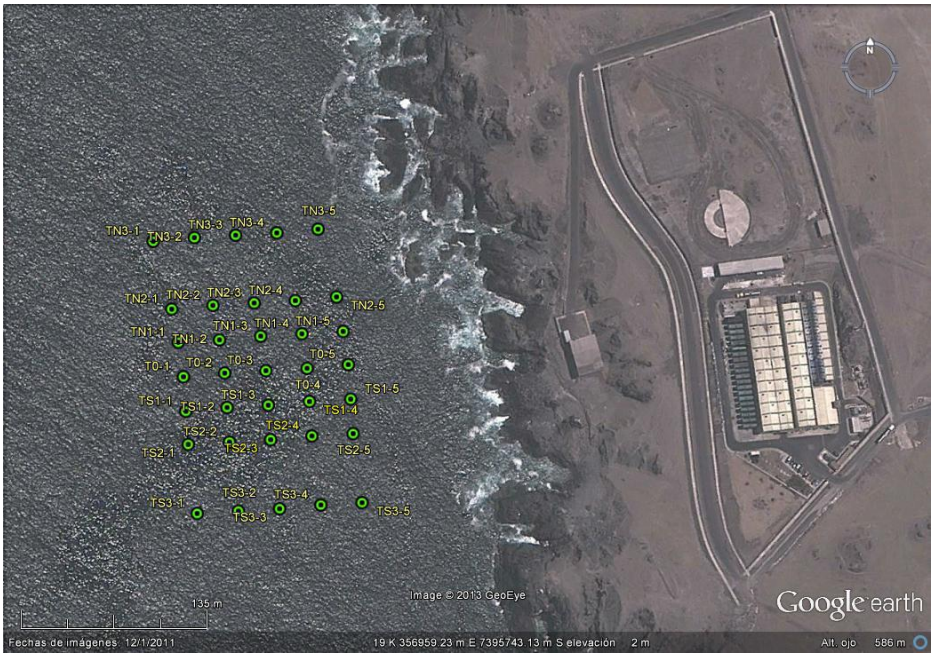
### 2.1 Sampling methodology

#### *2.1.1 Sampling design*

The characterisation of the macro benthic communities is determined in different monitoring stations located in the area surrounding the discharge zone. In 2010, 5 transects of 160 meters in length were defined, perpendicular to the brine discharge outlet, separated 30 meters apart. For each transect, 10 sampling stations were implemented at depths that varied between 10 and 18 meters. In 2012, as part of the results obtained in the previous study, 7, 120 meters long transects were defined, parallel to the brine discharge outlet. Each transect was divided into 5 sample stations, which were designated considering their position relative to the coast and the number of transects. The depths of the stations are the same as those considered in the 2010 study.




(a)




(b)

**Figure 1:** spatial location of transects and monitoring stations. (a) Transects arranged for the 2010 study; (b) transects arranged for the 2012 study.

### *2.1.2 Sample collection*

The sampling of the macro fauna was done with divers and the support of underwater filming. The species of flora and fauna were identified and a determination was made of the abundance of organisms and the coverage of species through 0.25 $m^2$ quadrants (Figure 2).

Also, a collection of individuals was made from a sector of the quadrant, in order to determine the biomass present, through drying and weighing techniques.

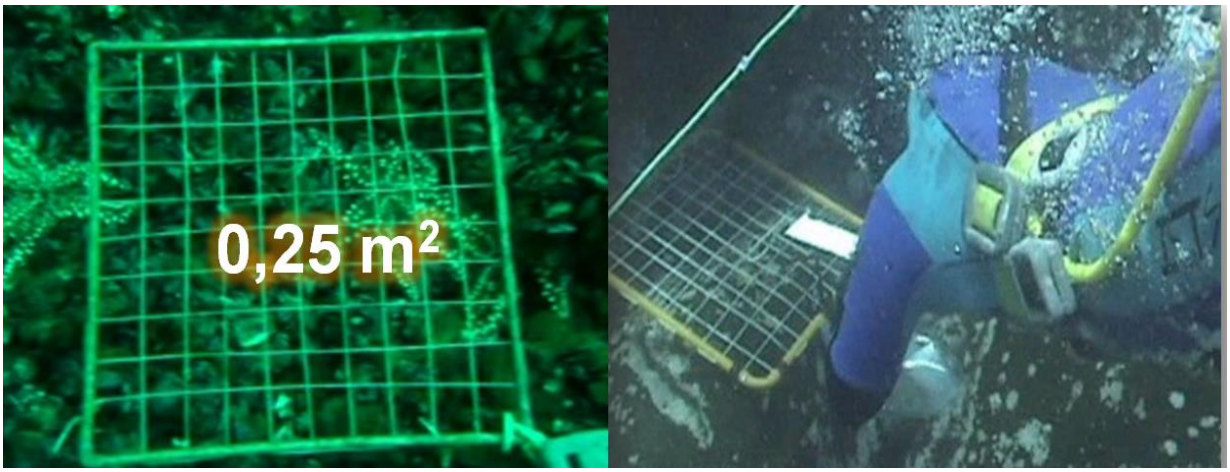



**Figure 2:** quadrant for determining abundance and coverage of species.

## 2.2 Analysis of data

The following parameters were determined to characterise the benthic communities:

- Abundance (total number of organisms of each taxa).
- Coverage (density).
- Biomass.

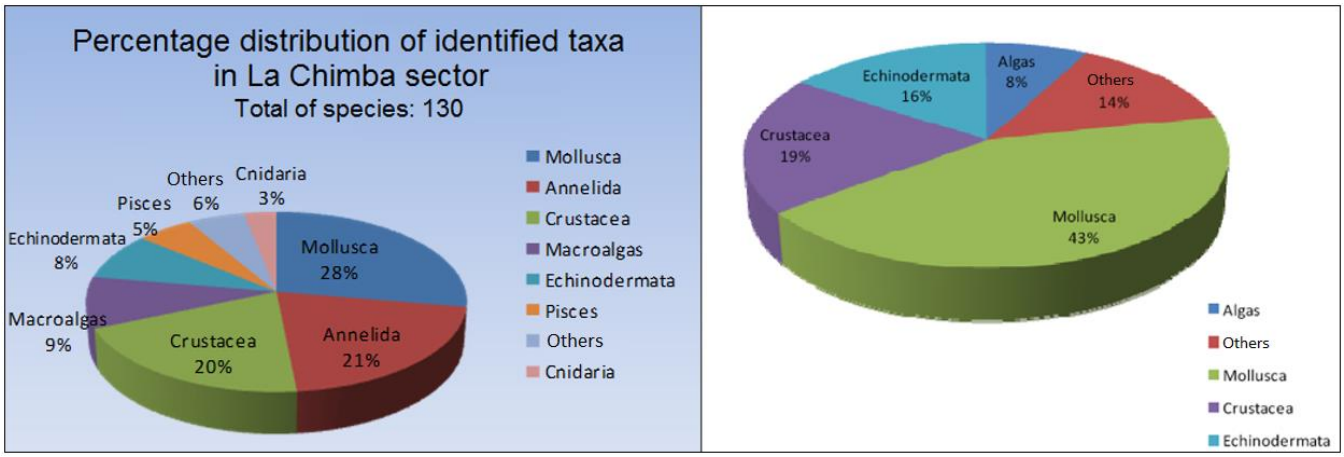
The species are identified with a stereoscopic microscope. The taxa of each sample are counted and weighted. Then, the number of individuals is recorded and their biomass is estimated based on dry weight. A univariate and multivariate analysis is also performed based on the characteristic parameters.

## 2.3 Results

### *2.3.1 Composition of species and biological characterization*

In relation to the campaign carried out in 2010, a total of 130 taxonomic units were recorded, corresponding to flora (macro algae) and fauna. The fauna consisted of invertebrate and vertebrate species.

The macro algae represent 9% of the total species (Figure 3); while within the invertebrate group there is a slight predominance of the Mollusca group (28%), followed by Annelida (21%) and Crustacea (20%). Found in lesser proportion are Echinodermata (8%), Pisces (5%) and Cnidaria (3%). The “Others” item combines minority groups such as Porifera, Nemertea, Priapulida, Platyhelminthes, Bryozoa, and Ascidiacea, with 6% of the total species.




(a) (b)

**Figure 3:** percentage contribution of taxa from sub-tidal hard bottoms. (a) Study carried out in 2010; (b) study carried out in 2012.

With regards to the study carried out in 2012, a total of 51 taxonomic units were recorded, which corresponded to algae and invertebrates, of which the Mollusca group was the dominant one, with 43% of the species, followed by Crustacea with 19% and Echinodermata with 16%. Other minority groups (Cnidaria, Porifera, Annelida and Bryzoa) contributed with a joint percentage of 14%, whilst algae contributed with 8% of the taxones (Figure 3, b).

The most characteristic species of the area were the molluscs, among which are: *Tegula tridentate*, *Aesopus aliciae*, *Thais chocolate* ("locate"), *Crepidula dilatata*, *Aulacomya ater* (mussel) and *Nassarius dentifer* and the Bryozoa, *Bugula neritica*, present in all of the measuring stations, with 100% occurrence.

### *2.3.2 Communitary parameters, abundance and biomass*

The total abundance of faunal organisms showed amounts that fluctuated between 698 individuals/0.25 $m^2$ and 5,547 individuals/0.25 $m^2$. The lowest abundance was recorded in T2 (transect N° 2) and the highest in T5 (transect N° 5) for the study carried out in 2010. In contrast to the total abundance of the faunal organisms obtained in the 2012 study, where values were recorded that fluctuated between 151 individuals/0.25 $m^2$ in transect TS3 and 342 individuals/0.25 $m^2$ in transect TS2.

Based on the numeric abundance of each taxa, the biocenotic indicators or community describers for each transect were determined, which are summarized in tables 3, 4 and 5, respectively.

The biocenotic indicators or community descriptors were obtained using a number of methods, including the Shannon Index, which is an equity index that comes from the information theory, therefore it requires all of the individuals to be randomly sampled and all of the species of the community to be represented in the sample [1].

In contrast to the Booststrap method, which is a non-parametric method as it does not assume the type of distribution of the set of data and does not adjust it to a determined model. This method is based on the proportion of the sample units that contains each species [1].

| Transect | Shannon Index | LL - UL (95%) Boostrap | Uniformity (J') | Simpson Index | Number of species | Abundance (ind./0.25 $m^2$) |
|---|---|---|---|---|---|---|
| T1 | 1.086 | 0.999 - 1.157 | 0.193 | 0.768 | 50 | 4,045 |
| T2 | 2.331 | 2.102 - 2.469 | 0.441 | 0.433 | 39 | 698 |
| T3 | 2.060 | 1.875 - 2.168 | 0.371 | 0.518 | 47 | 1,261 |
| T4 | 2.613 | 2.487 - 2.708 | 0.432 | 0.404 | 66 | 2,614 |
| T5 | 1.858 | 1.776 - 1.918 | 0.298 | 0.581 | 75 | 5,547 |
| $\bar{x}$ | 1.989 | | 0.347 | 0.541 | | |
| $\sigma$ | 0.579 | | 0.103 | 0.144 | | |

LL = Lower limit
UL = Upper limit

**Table 3:** ecological indicators of the hard-floor, sub-tidal community. The confidence intervals of the Shannon Index are indicated, estimated using the Bootstrap method with a 95% confidence level (2010).

| Transect | Shannon Index | LL - UL (95%) Boostrap | Uniformity (J') | Simpson Index | Number of species | Abundance (ind./0.25 $m^2$) |
|---|---|---|---|---|---|---|
| TN1 | 2.311 | 2.984 - 3.630 | 0.535 | 0.372 | 20 | 334 |
| TN2 | 2.013 | 2.881 - 3.633 | 0.474 | 0.474 | 19 | 287 |
| TN3 | 2.046 | 2.442 - 2.874 | 0.459 | 0.492 | 22 | 334 |
| TS1 | 2.153 | 2.846 - 3.611 | 0.600 | 0.309 | 12 | 257 |
| TS2 | 2.357 | 2.952 - 3.649 | 0.529 | 0.379 | 22 | 342 |
| TS3 | 3.457 | 2.999 - 3.638 | 0.744 | 0.188 | 25 | 151 |
| T0 | 2.466 | | 0.616 | 0.259 | 16 | 227 |
| $\bar{x}$ | 2.400 | | 0.565 | 0.353 | | |
| $\sigma$ | 0.428 | | 0.085 | 0.095 | | |

LL = Lower limit
UL = Upper limit

**Table 4:** ecological indicators of the hard-floor, sub-tidal community, of the mobile species. The confidence intervals of the Shannon Index are indicated, estimated using the Bootstrap method with a 95% confidence level (2012).

| Transect | Shannon Index | LL - UL (95%) Boostrap | Uniformity (J') | Simpson Index | Number of species |
|---|---|---|---|---|---|
| TN1 | 1.353 | 2.399 - 2.868 | 0.524 | 0.563 | 6 |
| TN2 | 1.619 | 2.399 - 2.868 | 0.697 | 0.384 | 5 |
| TN3 | 1.371 | 2.442 - 2.874 | 0.591 | 0.473 | 5 |
| TS1 | 2.137 | 2.005 - 2.841 | 0.827 | 0.279 | 6 |
| TS2 | 1.440 | 2.215 - 2.872 | 0.557 | 0.459 | 6 |
| TS3 | 0.989 | 0.834 - 1.130 | 0.383 | 0.625 | 6 |
| T0 | 1.425 | 2.385 - 2.864 | 0.713 | 0.421 | 4 |
| $\bar{x}$ | 1.476 | | 0.613 | 0.458 | |
| $\sigma$ | 0.301 | | 0.126 | 0.099 | |

LL = Lower limit
UL = Upper limit

**Table 5:** ecological indicators of the hard-floor, sub-tidal community, of the sessile species. The confidence intervals of the Shannon Index are indicated, estimated using the Bootstrap method with a 95% confidence level (2012).

Finally, the Simpson Dominance Index is a parameter that is the inverse of the concept of equity of the community. Takes into account the representativeness of the species with greater importance, without assessing the contribution of the rest of the species. Calculated determining the probability that extracting two random individuals from the community, the two were of the same species.

## III. DISCUTION

In 2010 a bank of "cholgas" (*Aulacomya ater*) was detected in the brine discharge area, which had not been recorded before. This bank of *Aulacomya ater* showed a greater biomass in the transects closest to the discharge, where mainly adult specimens were recorded, in contract to the presence of younger specimens in more distant areas, with lesser biomass. Similarly to what was detected in 2010, the Mollusca group predominated, both in terms of abundance and in biomass, in which the species *Aulacomya ater* remains the predominant one (2012).

The abundance of the "cholga" resource in the study area determines the high density of predator organisms that feed on them, such as the *Heliasther helianthus* (sea sun), *Meyenaster gelatinosus* (starfish) and *Thais chocolata* (a type of mollusc).

It was determined that the number of species increases according to the distance from the brine discharge. In the discharge zone itself, the presence of 39 different species was evidenced, while in the surrounding zones 50 species were recorded. On transects farther away, between 66 and 76 species were recorded. This distribution pattern is due to the settlement of *Aulacomya ater* in the discharge zone, since being mono-specific communities they generate a reduction in the variety of species due to the competition between them. For the 2012 study, the species *Aulacomya ater*, was present to the north of the discharge

with a continuous distribution between 15 and 17 meters depth, whilst the southern sector showed less coverage of this species.
On the more coastal transects, away from the discharge zone, the most abundant species is *Pyura praeputialis*, ("piure"), which plays a fundamental role since it facilitates the settlement of other species.

The presence of the species *Pyura praeputialis* had already been recorded in the monitoring in 2005. However, the dominant species *Aulacomya ater* was not detected that year.

Prior to the construction of the desalination plant, the study area was characterised by a low abundance of species, which suggests that the bank of "cholgas" detected would be related to the operation of the desalination plant and the brine discharge. Moreover, in 2010 there were 130 taxonomic units recorded, in contrast to the information from the monitoring campaigns performed in 2002, which indicated the presence of 44 taxonomic units, which was ratified during 2005 and 2008. It should be mentioned that during 2010 the Plant increased its production to 450 litres per second, while in 2008 and 2005 the volumes of flow of production were 300 litres per second and 150 litres per second, respectively. The Plant's current production, starting in 2011, is 600 litres per second.

Another important point to compare from the studies carried out in 2010 and 2012, is in relation to the fact that in 2010, the measurements covered a more coastal sector (5 meters depth), where *Pyura praeputialis* is abundant. This organism allows the proliferation of fauna associated with it, increasing the specific abundance of the coastal area. It should also be mentioned that the 2010 study included comparatively more sampling stations, which results in a larger number of sectors analysed.

## IV. CONCLUSIONS

1. The brine discharge favours the settlement of species, mainly a bank of "cholgas" (*Aulacomya ater*), which is widely developed in transects closest to the brine discharge. The variations in salinity recorded around the discharge would create conditions appropriate for the settlement of this species.

2. The argument goes that brine discharge is a determining factor in the establishment of banks of "cholgas", such as the one that currently exists in the study area.

3. The coastal transects farthest from the brine discharge evidence the predominance of *Pyura preaputialis*, although young specimens of *Aulacomya ater* are also recorded in these sectors, with a discontinuous distribution along the transects.

4. The study area shows a high richness of species, such as starfish or molluscs, in response to the bank of "cholgas".

5. The shallowest sectors (close to the coast) evidence a greater richness of species due to the presence of *Pyura preaputialis* ("piure").

6. In general terms, the composition of species associated with the bank of *Aulacomya ater* in La Chimba is similar to those reported in the La Rinconada Marine Reserve of Antofagasta, where there is a bank of *Argopecten purpuratus* (northern scallop), so no adverse effects of the brine discharge are seen on the biota of the area due to the presence of species that coexist in another bank of molluscs in Bahía Moreno. There is also no change recorded in the composition of species compared with that reported in

the La Chimba plant project EBL (Environmental Baseline), namely, the environmental studies carried out in the area prior to the construction of the desalination plant.

7. Comparing the study carried out in 2012 and the monitoring reported in the PVA (Environmental Surveillance Plan) of 2010, the presence of *Aulacomya ater* remains as the main resources, making up a bank in the area, as well as the coexistence of predators such as echinoderms (especially starfish) and molluscs (*Thais chocolate*).

8. The difference in the number of species recorded in 2010 and 2012 (130 and 51 taxa respectively) is associated mainly with the fact that the measurements from 2012 covered a wider area that considered the coastal sector.

## V. REFERENCES

1. Moreno, C. E. 2001. Métodos para medir la biodiversidad. M&T–Manuales y Tesis SEA, vol. 1. Zaragoza, España, 84 pp.

## APPENDIX I

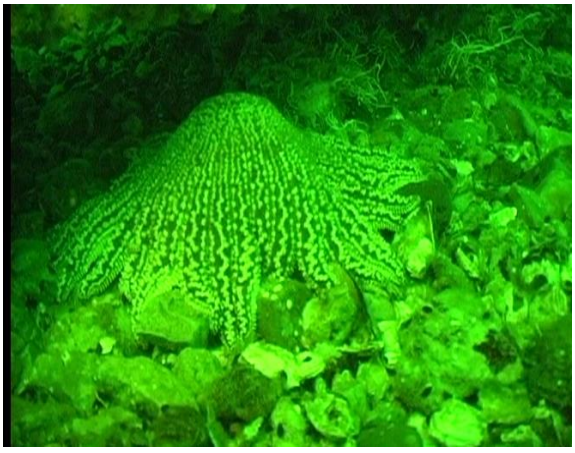
Photographs of some of the species recorded during the study:

*Thais chocolate* (“locate”)

*Aulacomtya Ater* (“cholga”)

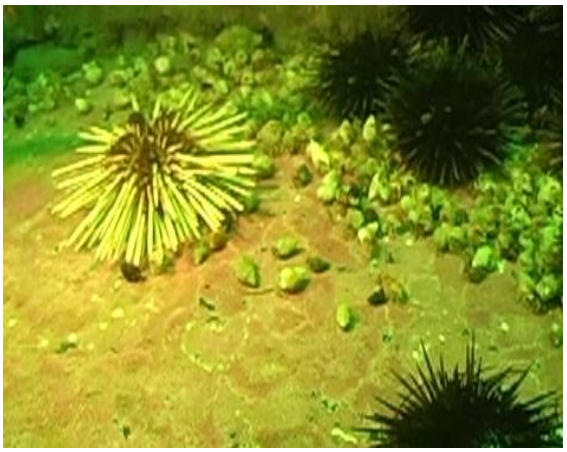
*Anthothoe chilensis* (“actinia blanca”)

*Austromegabalanus psittacus* (“picoroco”)



*Heliaster helianthus* (sol de mar)

*Loxechinus albus* (erizo rojo)

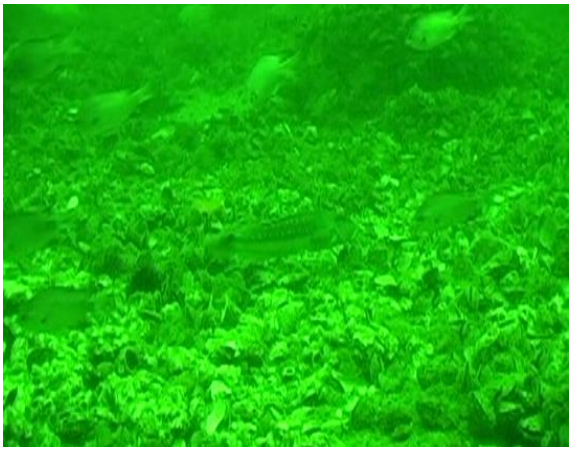


*Tetrapyygus niger* (“erizo negro”)

*Isacia conceptionis* (“cabinza”)

*Chromis crusma* (“burrito”)

*Cheilodactylus variegatus* (“bilagay”)



(*Pinguipes chilensis* (“rollizo”)

View of one of the brine discharge diffusers