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"AN OPEN SOURCE SCRIPT THAT CONVERTS SIMRAD EK60 AND EY60 ECHOSOUNDERS PLAIN DATA INTO VISUAL RESULTS TO DETERMINATE NAUTICAL AREA SCATTERING COEFFICIENT OF ECUADORIAN SMALL PELAGIC RESOURCES"

CAPSTONE PROJECT REPORT

Previous to the obtention of Degree:

OCEANIC AND ENVIRONMENTAL ENGINEERING

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I dedicate this thesis to my parents, Mariana and Marcelo, for their endless love to me and for their support during all my career. Thanks for always being there for me, this is for you.

Also, to my little sister Camila and my big brother Ricardo.

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I dedicate this project to my family:

Hugo, Pilar, Hugo Daniel and Juan David.

Gabriela

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EXPRESS STATEMENT

"The responsibility and authorship of the content of this Graduation Project, corresponds exclusively to us; and we give our consent to ESPOL to publicly communicate the project by any means to promote consultation, diffusion and public use of intellectual production"

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ABSTRACT

Nowadays underwater acoustics is widely used as an important tool for fishery science. The National Fisheries Institute (INP, acronym in Spanish) is in charge of strategically managing fisheries for sustainable development throughout the national territory.

The main reason for working on this project is that acquiring the licensed software Echoview is expensive. Therefore the need to propose low-cost solutions to real problems of the sustainable management led us to develop this project. We integrated interdisciplinary subjects involving oceanography and fisheries that we learned through the entire career to make this possible.

The present job is a low-budget solution for INP. Because of that we developed the script in an open source tool “RStudio” capable of doing the post-processing analysis. The product was adapted for the visualization of small pelagic fish schools to determinate the Nautical Area Scattering Coefficient (NASC). Moreover validations of LP script were based on accuracy and precision against the licensed software Echoview. The script LP is accurate in 7.2% and precise in 0-11%. The main source of uncertainty was given by the operator and the method of school selection. Of course further modifications can be done according to the user’s requirements.

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INTRODUCTION

Ecuador has privileged oceanographic conditions that lead to have rich fisheries resources. These represent an importance to the balance of the marine environment and to the national economy. Nowadays there are a lot of acoustic techniques applied to investigate fisheries including equipment and software.

This research is essential for sustainable management of fisheries resources.

The National Fisheries Institute (INP, acronym in Spanish) is the public entity in charge of monitoring the fisheries resources in Ecuador through its programs. One of the processes is destined to keep a track on small pelagic resources by hydroacoustic surveys.

Thus INP needs to quantify the presence of small pelagic fish located in continental Ecuador using SIMRAD's echo sounder EK60. Hence, the main problem is the expensive/high price of the licensed software Echoview to process INP´s echo sounder SIMRAD model EK60 data. Moreover, there are not known open access alternative tools available to evaluate Ecuadorian fishery resources.

Additionally, through the literature review, we found few options to solve the problem. The package echogram programed by Hector Villalobos was selected as the most suitable guide to develop the script described in this project.

The script was executed in "R Studio" open source software for statistics calculations to develop a routine and satisfy INP need.

The main objective of this project was to develop a script in the statistical software "R Studio" that reads, processes and visualizes SIMRAD EK60 and EY60 plain echosounder data through an echogram. Hence, we obtain the Nautical Area Scattering Coefficient (NASC) of small pelagic resources in Ecuador.

The specific objectives are:

1. Investigate the existing alternatives of solution to solve the problem.
2. Compile the useful functions adapting them to Ecuadorian environmental conditions.
3. Establish the work routine of the script for the NASC quantification of Small Pelagic Fish.
4. Validate the script results through several runs and against reliable data from the trial version of Echoview.

The first chapter consists of the literature review. This chapter includes a general revision of the different applications involving "R Studio", underwater acoustics and small pelagic fish.

The final sub section of this chapter gives the reader information about small pelagic resources management using underwater acoustics in Ecuador. The main goal of this chapter is to describe the potential market of our product.

The next chapter will give the reader the necessary information to understand our product. It includes a brief description of INP and its programs from where our product will be used. It also includes the main species of interest for national economic importance, the same ones that are constantly monitored by INP. The next chapters give basic concepts used in hydroacoustic fisheries science and the methodology applied in hydroacoustic surveys.

Chapter 3 describes the methodology for the script development. It explains step by step how the script LP works in each code line with its respective results shown in figures and tables.

On chapter 4 we present the validation of the script LP. Different methodologies are described for accuracy and precision validation. The first subchapter consists in test Echoview accuracy by comparing NASC values for 3 files with more than one school, selecting them twice in the trial version of Echoview. In the second subchapter we compared NASC values for those same files using script LP. The next subchapter compares NASC values for the total of the files with both methodologies simultaneously. Finally we determinate the precision of script LP by running the 155 files twice obtaining NASC value for each run.

CHAPTER 1

1. LITERATURE REVIEW

This chapter includes a general review of existing jobs related to this project. It is divided into four main parts: Applications based on “R Studio” aimed to pelagic fish, underwater acoustic applications for small pelagic resources, “R Studio” applications based on underwater acoustics, and the role of Ecuador in underwater acoustics for small pelagic resources management. The latter sub-section focused on understanding the local background of the project.

1.1. Applications based on “R Studio” aimed to pelagic fish

“R Studio” statistical software has been widely used for data management because of its friendly interface. Although used by econometricians, academics also seem to feel comfortable with its platform-independent nature [1]. The scientific community knows the statistical capabilities of the tool and its approaches to pelagic fisheries management [2][3][4]. In addition, researchers use “R Studio”’s diversity statistical functions, plotting range and processability strength for pelagic fish investigation [5][6][7][8]. It is also used to determine ecological features of pelagic fish [9].

Furthermore, the following applications focus into scripting and package developing with “R Studio” related to pelagic fish. In [10] it is presented an online tool to run stock assessment models following a couple of easy steps, developing a Virtual Research Environment (VRE) code. The code allows to edit online numerous steps involved in the stock assessment process. The researchers used a stock of yellowfin tuna (*Thunnus albacares*) provided by the Indian Ocean Tuna Commission (IOTC) as an example for the runs. Among the web services included in the VRE code, in [10] it is used R Studio server to manage data online. Hence, the tool enhanced online collaboration between the scientific and academic communities.

Additionally, Hidden Markov Models with ocean data **(**HMMoce**)** is an R package which improves marine animal position estimates. It compares electronic tag data of fish to oceanographic data such as depth-temperature profiles, sea surface temperature, etc. [11]

Another, statistical method called *generalized additive model* (GAM) was simulated in R Studio using gam function of the “mgcv package” using catches data from albacore tuna (*Thunnus alalunga*). The model combined sub-surface temperature, salinity and chlorophyll as variables. Thus, it determined which variable was the decisive environmental parameter for the vertical abundance of this species in the Eastern Indian Ocean (-14°S to 2°S – 92°E to 121°E). [12].

In [13] it is developed another “R Studio” application involving modeling, to build ecological index based on Principal Component Analysis (PCA). This application determined the correlations between each functional group for a fish community in De la Plata River.

Among “R Studio” applications related to acoustic data processing, [14] found a package, called EchoR. The researcher described it as a tool for the assessment of pre-processed fisheries acoustics data that comes from sea surveys. In addition, the tool is useful for determining standard echosystemic indicators based on those data [14]

We could use this last tool as a guide for the next step into species biomass estimation. Thus, our script LP will use the results from script and biological parameters registered after exploratory fishing. In fact, acoustic biomass estimation procedure needs collection of different data from a cruise track, such as total fish acoustic backscatter, species mean length and proportion by species and/or size class [15]

1.2. Applications using underwater acoustics for pelagic fish

Underwater acoustics focuses on echo sounders. In 1920, scientists invented echo sounders applying the theory of echolocation. According to International Council for the Exploration of the Sea (ICES), in 1930, echo sounders detected fish. [44]

In contemporary underwater acoustics, there is a difference in applications of echo sounders depending of the group of animals of interest. These could be marine mammals (their behavior) or non-mammals, which includes fishes (finding, counting ad catching them) [16]. Currently, underwater acoustics applications are widely used in fishery science for the estimation of biomass, abundance and distribution of fish stocks.

Among several techniques for estimating fishery resources, we have fish counting and echo integration (further explained in Chapter 2). These techniques will depend on survey’s objective. For example, if the goal is to quantify by individual fish, the technique used will be fish counting. However, if the goal is to quantify schools, the technique will be echo integration.

In this section, we review alternative tools for processing of hydroacoustic data.

NAME	DESCRIPTION
Echoview	Software package for hydro acoustic data processing. It is capable of water-column and bottom echo sounder data processing [17]. It works with algorithms and allows operations between matrices (echograms). For its efficiency, this software is one of the most used for the post-processing in fishery science.
Echoshape	Interactive post-processing program that writes hydro acoustic data to a database, performs data analysis, and displays results. It is straightforward for selecting individual fish traces or fish schools from data files output by HTI Model 240-series Split-Beam Systems [18]. The program can instantly retrack and display fish traces multiple times.
LSSS	Tool for stock assessment and ecosystems monitoring [19]. It interprets data from multi-frequency echo sounders. Also, it provides functions online, post-processing mode offshore and onshore. This software also reads collected raw data for school detection. The tool can easily process large amounts of historic data for resource management and research purposes.
Sonar 4 and Sonar 5-Pro	Components of Sonar X it is recommended by SIMRAD as scientific post-processing software. We can use them in aquatic environments like oceans, large rivers, lakes and ponds. Sonar 4 specialty centers in the abundance estimation. In addition, Sonar 5-Pro is a tool that processes biomass, tracking, macrophytes, target classification and multi frequency analysis of echo sounders multi-beam [20].
EchoviewR	The R package EchoviewR is an interface between Echoview and R using COM scripting [21]. [22] shows EchoviewR application in two projects to validate its efficacy in fishery resources estimation. The first project was the estimation of krill biomass in North Eastern Antarctica. The second project was krill swarm detection and classification. The researchers developed the package to automate repetitive tasks by providing some tools to process data in a faster way by scripting.

	Echoview itself validated it.
Echonix	This package is a library that analyses hydroacoustic data in the programming language Python with support for EK60 echo sounder data in RAW format [23]. It also provides data analysis tools of high quality for the scientist in hydro acoustic field.

TABLE 1. APPLICATIONS BASED ON UNDERWATER ACOUSTICS FOR PELAGIC FISH.

1.3. Applications using underwater acoustics combined with "RStudio"

This section focuses on applications developed in "R Studio" applied to underwater acoustics. We found few applications that involve underwater acoustics. Each application is described below in table 2:

NAME	DESCRIPTION
Acoustic.R	*Active hydroacoustic data processing* It is a set of utilities for the processing, manipulation and synthesis of active hydroacoustic data [24]. This package that also needs Echoview to eject its script, allows the user to open, save, close, and create an Echoview file (.evi).
Oce	The package *oce* [25] has some functions related to hydroacoustics: • *Read.echosounder,* this function reads Biosonics echo sounder data only and determinates (count) the amplitude values, not decibels (dB). • *Findbottom,* it determinates the bottom by finding the strongest reflector that will represent seabed. • *Echosounder-class*, it helps to store echosounder´s data class based on what it is described in the data, usually it is a list with instrument position, coordinates, depth, signal amplitude and angles. • *Plot echosouder method,* plots echo sounder data with simple linear approximation method. It shows values in axis x and y in plot units. • *Subset echo sounder method,* this function subsets data

	by time or by depth separately. It is important to mention that all these functions work only with data referred to **Biosonics echo sounder**.
Sonar	This package was develop to calculate sound velocity, water pressure, depth, density, absorption and sonar equations (includes source level, propagation loss and target strength) through formulas [26].
V-track	It is a group of R functions designed to store, analyze and visualize detection data from the VEMCO set of receivers and transmitters. V-Track contains a number of tools for analyzing your passive acoustic detection data by telemetry within a central database [27].
Echogram package	This package was developed by H. Villalobos; it is very useful to import multi frequency acoustic data stored in .hac files producing echogram visualization. The package has a total of 15 functions that are capable of merging, masking, adding and joining echograms, deleting unwanted areas and removing noise associated with the marine environment from echograms [28].

TABLE 2. APPLICATIONS USING UNDERWATER ACOUSTICS IN "RSTUDIO".

1.4. Underwater acoustics applied to small pelagic resources management in Ecuador

The small pelagic fishery in Ecuador began in the decade of the 60's with the main goal of producing fish meal and canned seafood [29]. These fishery resources consist of species like: mackerel (*Scomber japonicus*), pinchagua (*Opistonema* spp.), chuhueco (*Cetengraulis mysticetus*), round sardine (*Etrumeus teres*), southern sardine (*Sardinops sagax*) and chub mackerel (*Scomber japonicus*) [30]. Small pelagic fish distribution is mostly coastal up to 70 nautical miles offshore including areas as Gulf of Guayaquil, coasts of Manabí and Esmeraldas [29]. In the period between 2005- 2015 small pelagic fish catches in Ecuador had a yearly average of 229,000 MT [31]. Yearly fluctuations are shown in figure 1.

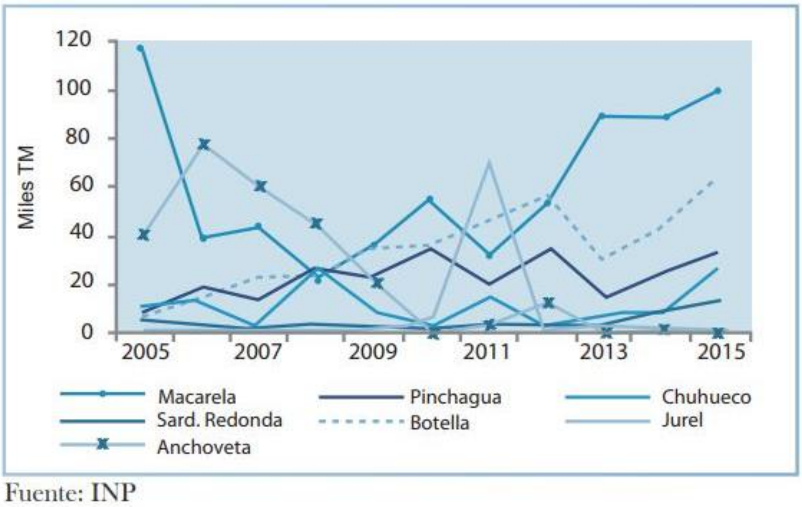


FIGURE 1. RECORD OF SMALL PELAGIC FISH CATCHES IN ECUADOR FROM 2005-2015. SOURCE: ESPAE, 2016.

Small pelagic fishery has a major role into Ecuador's economy. For this reason, The National Fisheries Institute (INP) monitors constantly these resources by monthly visits to the main ports and beaches where fishing catches are discharged. Also, they register data from processing plants of fish meal, oils and canned products [32]. This procedure is a direct method to evaluate fishery stock, indirect methods consist on hydroacoustic surveys [33[.

The oldest record of hydroacoustic surveys in Ecuador is from [34], developed by INP. These surveys consist of hydroacoustic prospection and exploratory fishing for small pelagic resources. INP performed these surveys with their scientific vessel TOHALLI. The main objective of these surveys was to

determinate spatial distribution (square nautical miles), biomass (tons) and abundance (number of individuals) of the main small pelagic fish species [33].
INP uses EK60 scientific echo sounder to record acoustic data. The data involves echograms with Sv values, target strengths and angular coordinates. INP needs this information for reflectivity analysis and echo integration. However, all the colleted data must be analyzed and needs to go through a post-processing software Echoview has been used for this in the past few years [33].
All of the tools described above needs a license that implies costs and times, so an important alternative is necessary.

CHAPTER 2

2. THEORETICAL PROJECT BASIS

This chapter includes a brief review about the official institute in charge of researching fish and the theoretical basis about Underwater Acoustics aimed to small pelagic fish resources in Ecuador. In addition, it is given a general description of the computing tool used to develop a statistical script based on R Studio; an open source software.

2.1. The National Fisheries Institute

The National Fisheries Institute (INP) is a public entity created on 1960 with headquarters in Guayaquil dedicated to biological, technological and economic research, aimed at the management and development of fisheries by FAO (Food and Agriculture Organization) recommendation (Executive decree No. 1321 - October 18th, 1966).

INP along with the Undersecretariat of Fishery Resources is in charge of strategically managing fisheries for sustainable development throughout the national territory.

Its mission is to provide services and advice to the fishery-aquaculture sector through research and scientific-technical evaluation of hydrobiological resources and their ecosystems for their sustainable management. Its vision is to be the leading institution in scientific-technical research applied to the sustainable use of the hydrobiological resources of the Southeast Pacific region. [35]

INP provides bioaquatic resources research, library and Bioaquatic Resources and their Environment Research (IRBA, acronym in spanish) laboratories. IRBA processes include two sub-processes; Elaboration and Execution of projects (EEP) and Elaboration of Bioaquatic Resources Projects and their environment (EPRBA, acronym in Spanish) [36]. EPRBA develops scientific research in fisheries, aquaculture and environment, the current programs are:

- Climatic Variability
- Aquaculture
- Fishing Statistics
- Fisheries
- Research Surveys
- IRBA Laboratories

- Other fishery reports

This project is related to two of INP's programs; Fisheries and Research surveys. The programs' objectives are determinate the stock (population status) of the main species of small pelagic fish and, the characteristics of this fishery to recommend management measures. INP's research vessel B/I Tohalli (Figure 2) can operate oceanographic surveys and fishing surveys; experimental surveys or trawl surveys. These surveys use hydroacoustic application as a tool to capture target fishery resources.

FIGURE 2. RESEARCH VESSEL TOHALLI.
SOURCE: INP, 2013

2.2. Small pelagic resources in Ecuador

The purpose of this section is to review species that INP keeps track on during hydroacoustic surveys.

Since 1981 INP has monitored the purse-seine (Figure 3) fleet through one of their programs called "Small Pelagic Fish Program". The main objective of doing this is to gather information about biological and fishing characteristics. This monitoring helps to evaluate the state of fishery resources and generate recommendations about their management.

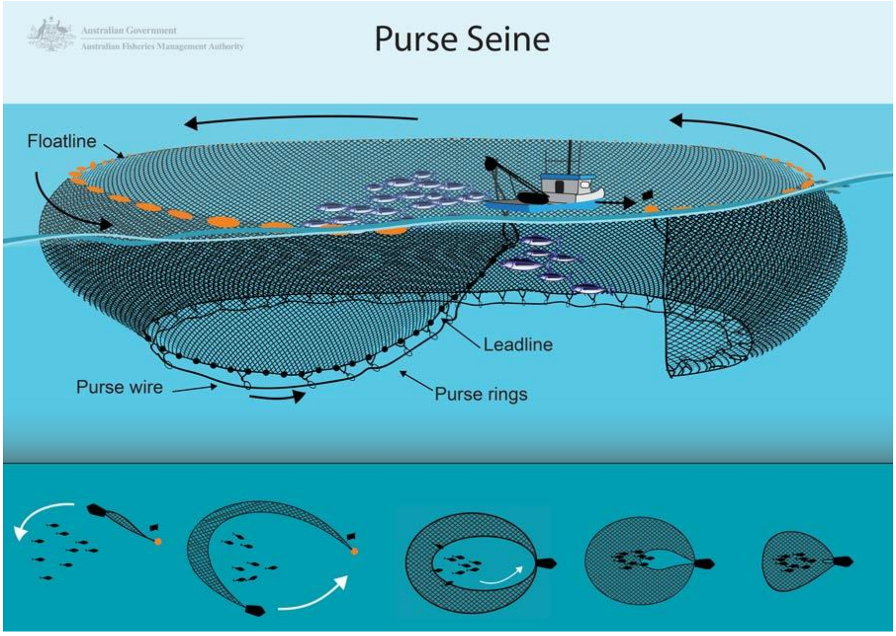


FIGURE 3. ILLUSTRATION OF PURSE-SEINE FISHING. SOURCE: AUSTRALIAN FISHERIES MANAGEMENT AUTHORITY.

Small pelagic fish, also known as coastal pelagic, are fish of small size that tend to move in large banks along the continental shelf close to the surface. They have high fertility and fast growth rate [31].

Among the principal species that INP monitors [37] (Figure 4) are: pinchagua (*Opisthonema* spp.), chuhueco (*Cetengraulis mysticetus*), chub mackerel (*Scomber japonicus*), southern sardine (*Sardinops sagax*) and others like round sardine (*Etrumeus teres*), boltellita (*Auxis* spp.) and anchovy (*Engraulis ringens*) [38].

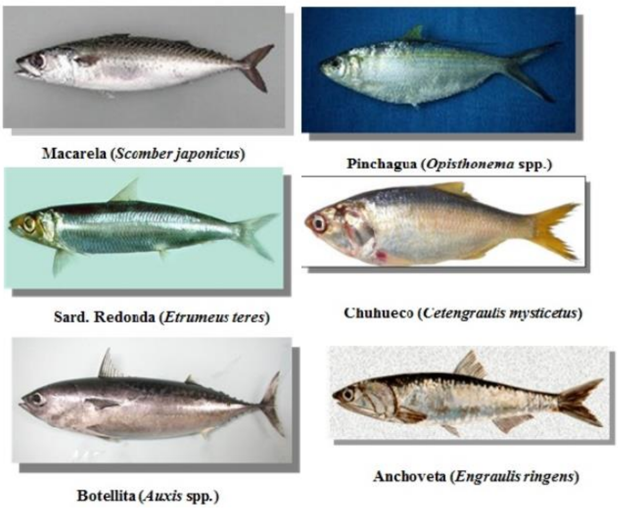


FIGURE 4. MAIN SMALL PELAGIC SPECIES OF STUDY FOR INP. SOURCE: INP.

Pinchagua (*Opisthonema* spp.)

Coastal pelagic species distributed along Ecuadorian coastal profile (from Bahía de Caráquez, Manabí province to Gulf of Guayaquil). *O. bulleri, O. libertate, O. medirastre* and *O. berlangai* are the four species of pinchagua detected in Ecuadorian sea. However, they are difficult to distinguish by morphological features and, for research purposes they are grouped into *Opisthonema* spp (Figure 5). Pinchagua can reach 30 cm [39] although [33] reported a maximum length of 22 cm in 2013. This species feeds on larvae and pelagic fish eggs, zooplankton and pelagic crustaceans [38].

FIGURE 5.PINCHAGUA (OPISTHONEMA SPP.). SOURCE: INP.

Chuhueco (*Cetengraulis mysticetus*)

Marine, pelagic and inshore fish distributed along the eastern central pacific including Ecuador's sea. Chuhueco (Figure 6) forms large schools breaking up and reforming in short time. This species feeds on diatoms, silicoflagellates, dinoflagellates and small crustaceans. Chuhueco's size is around 14-15 cm. [40]

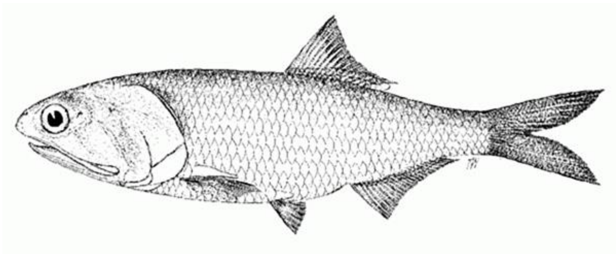


FIGURE 6. CHUHUECO (CETENGRAULIS MYSTICETUS). SOURCE: FAO.

Chub mackerel (*Scomber japonicus*)

Marine, pelagic-neritic fish distributed across Pacific Ocean. The length of this species can reach 64 cm maximum. Chub mackerel's diet consists of copepods, crustaceans, smaller fish and squids. This species usually forms schools with other species like *Sardinops sagax*. Chub mackerel (Figure 7) schools remain inactive during winter and moves deeper in water [41].

FIGURE 7. CHUB MACKEREL (SCOMBER JAPONICUS). SOURCE: FISHBASE.ORG.

Southern sardine (*Sardinops sagax*)

Marine, pelagic-neritic fish distributed from southern Africa to the eastern Pacific. This species (Figure 8) can reach 39.5 cm long and can live up to 25 years. Southern sardine feeds on planktonic crustaceans such as copepods [42].

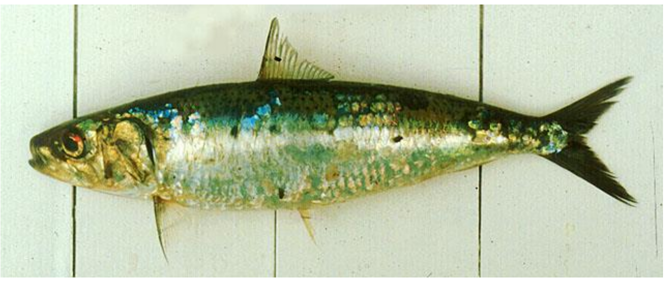


FIGURE 8. SOUTHERN SARDINE (SARDINOPS SAGAX), SOURCE: FISHBASE.ORG.

2.3. Introduction to Underwater Acoustics

In this section acoustic fishing basic principles is described.

Underwater acoustics in the ocean plays the same essential role as a radar and radio waves in the atmosphere and in space [43]. It has plenty of applications in science as fisheries management [44] (Figure 9), seabed type and submersed aquatic vegetation determination, bathymetry and marine geophysics applications.

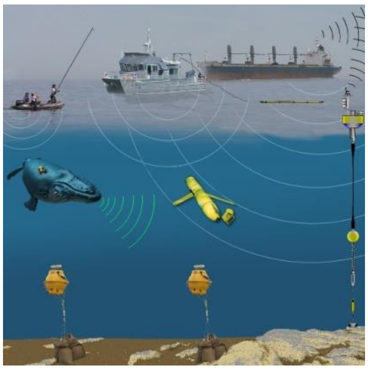


FIGURE 9. UNDERWATER ACOUSTIC APPLICATIONS. SOURCE: MIKE THOMPSON, NOAA/SBNMS)

Fisheries acoustics is the science that uses acoustic techniques to obtain information as the detection and precise location of fish [45]. This information can be acquired by post-processing techniques to estimated biomass, abundance and distribution of fisheries resources (Figure 10).

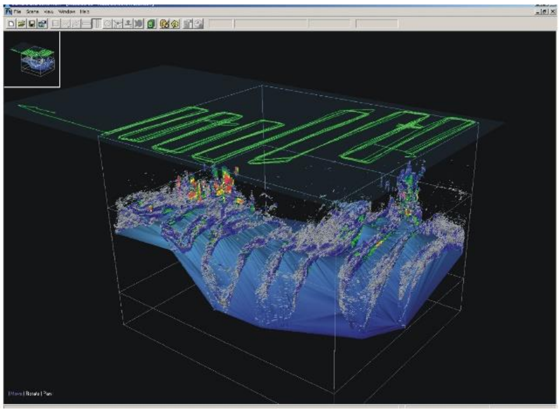


FIGURE 10. FISHERIES ACOUSTIC APPLICATION 3D. SOURCE: NOAA

SONAR stands for Sound Navigation and Ranging, it is a term for a device or instrument that can detect and measure underwater sound of objects called targets. Sonar involves listening to sound energy from targets sound energy they reflect (echo). There are passive sonars (hydrophones) and active sonars (echo sounders) [46].

FIGURE 11. SIMRAD EY60 ECHO SOUNDER. SOURCE: SIMRAD

An echo sounder consists of a transducer (hydrophone) and a transceiver (box of electronics). There are many types depending of their applications (scientific, commercial, etc) but all of them divided into two categories; Singlebeam echosounder (SBES) or Multibeam Echosounder (MBES). An echosounder measures voltage over time (sound energy). An example of a scientific echosounder is shown in image 11 from SIMRAD Company.

An echogram is a compilation of echo intensity versus depth; it is like a picture beneath the sea surface [47]. An echogram (figure 12) has a data frame that registers information of depth, ping time or navigated distance, and Sv (volume backscattering coefficient) measures in decibels referenced to 1 m2/m3. [48].

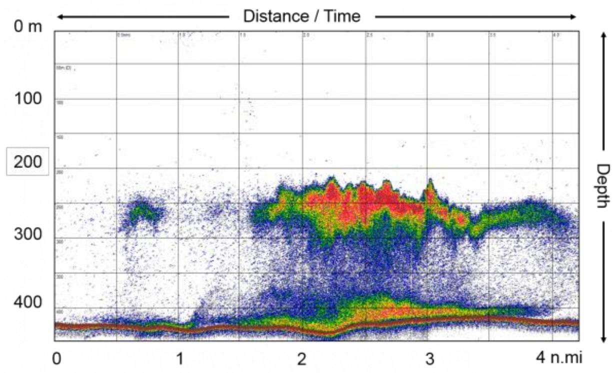


FIGURE 3. EXAMPLE ECHOGRAM HTTPS://MARINEDATA.NIWA.CO.NZ/FISHERIES-ACOUSTICS-TRANSECTS/

NOMENCLATURE:

Scattering is when the sound in the water meets a solid object and some energy is scattered. Scatter is a term referred to the energy sent in different directions. “Backscattering” is referred to the part that goes back to the source. The factors that determine scattering are animal physiology; internal organs, impedance, size and shape and orientation [47].

Sv_is the volume backscattering strength [49], defined by the ratio of intensity of sound scattered back in the direction of the sound source by a unit volume to the intensity of the incident plane wave [50]. It is calculated by:

$$S_v = 10 \log_{10} s_v \quad (2.1)$$

Where: s_v is the volume backscattering coefficient.

dB is the symbol for decibel which is the unit of sound intensity measurement [51].

Channel is referred to the frequency of data. All files from an echo sounder have different frequency data, where channel 1 is the data working with 38 KHz frequency and channel 2 is the data working with 120 KHz.

Pings: timeslots or distance intervals [52].

NASC: Nautical area scattering coefficient or S_A is a measurement of area scattering [49]. It is a cumulative average of backscattered acoustic energy [52] and it is calculated when integrating a region to export as analysis variables. Its units are $m^2\ /nmi^2$ and its defining equation is:

$$NASC = S_A = 4\pi(1852^2)\int_{z_1}^{z_2} S_v\, dz \quad (2.2)$$

Where

S_v = mean volume backscattering strength of the domain being integrated.

z = mean thickness of the domain being integrated (m)

1852 = meters per nautical mile (m/nmi) [53]

NASC is also called an echo integration referred as the sum of echoes used in fishery resource evaluation to know abundance and biomass of species. [52] The Noise term refers to the environmental (ocean) noise such as waves, winds, currents and biological noise, also the vessel noise including the propeller motor, cavitation and vibration, and finally electric and thermic as the non-audible noise [52].

2.4. Acoustic surveys methodology

The methodology described in this section for acoustic surveys is based on INP methods according to Romero et al. 2015.

The hydroacoustic prospection follows a systematic sampling system. It consists of parallel profiles perpendicular to the coast depending on bathymetry from the area. There is a separation of 5 Nautical Miles between each profile. This system allows evaluation of the collected data in equal proportions. The technicians also need to define a value for the Sampling Unit*. INP technicians generally use 1 NM interval as sampling unit to report NASC measurements.

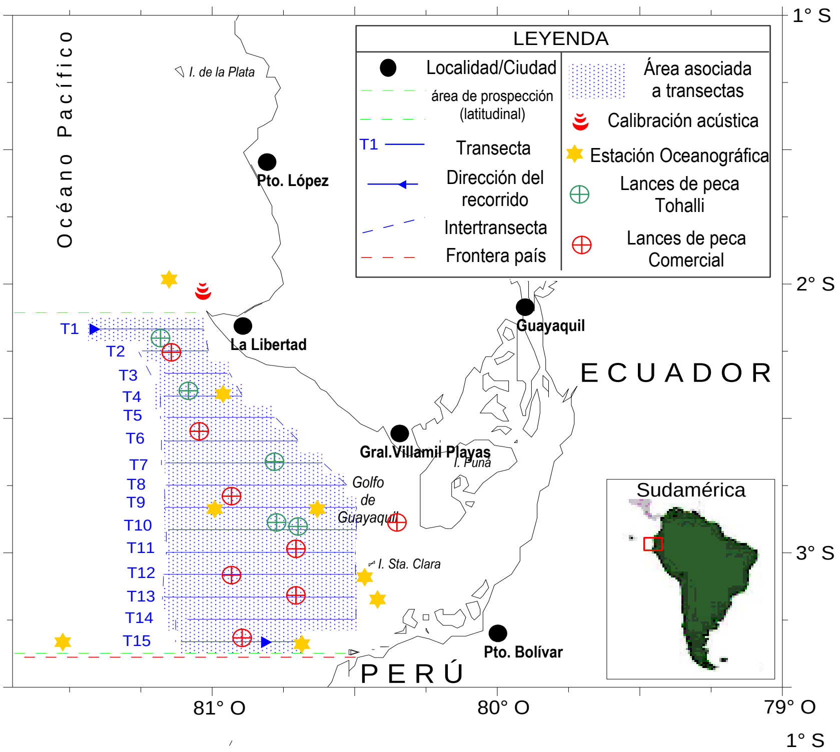


FIGURE 13. SCHEME OF INP'S HYDROACOUSTIC SURVEY T13-10-02P. BLUE LINES REPRESENT THE CRUISE TRACK PROPOSED ACCORDING TO ISOPARALLEL SAMPLING METHOD. SOURCE: ROMERO ET AL., 2015.

During the hydroacoustic surveys, researchers collect data as Sv values, target strength for species and angular coordinates. Then, they perform reflectivity analysis and echo integration. SIMRAD's EK60 scientific echo sounder is the equipment INP uses to record echograms.

After the survey is over, INP's acoustician performs data analysis with Echoview post-processing software (Myriax, Australia). Along with the results from echo integration and exploratory fishing data, the technician determinates spatial distribution of resources. The formulae given by [54] allows to estimate biomass and abundance:

Target strength (TS) or acoustic size is a measure of the reflection coefficient of the target that is quantified as a number of negative decibels. For fish target strength it comes from the swim bladder [55].

$$TS = 20\ Log\ L - b20 \quad (2.3)$$

L is length of the fish in cm and b20 (in dB) is a factor dependent on the reflective characteristics of the target (based on morphological similarity by species).

Abundance or fish density is a measure of the amount of fish in a given area. It is measured in# $individuals/mn^2$. Fishery scientists collects data for both the amount and fish size [56].

ρ = *NASC / σ* (2.4)

σ = 4π (10TS/10) (2.5)

Biomass is the mass (weight) of living biological organisms in a given area or ecosystem at a given time [57]. Its units are$tons/mn^2$. It is a good estimator of the total stock condition, fishing pressure, habitat conditions and recruitment (exploitable population [58]) success [56]. It is calculated for each transect based on the average weight (w) of each fish.

w = *aLb* (2.6); a and b are constants defined by species, **L** is length of fish

Once an area A is calculated for each isoparallel area, the biomass is estimated with the following equation:

B = *ρAw* (2.7)

Consequently, the evaluators make a contour chart for the spatial distribution of species, as well as plotting level curves that show acoustic densities for each species [59]. Lastly, density values are interpolated by choosing the most appropriate method. INP presents final results through maps of acoustic density spatial distribution.

2.5. R Studio statistical software

“R Studio” is an open source professional software; an integrated development environment (IDE) for R [60] founded by Joseph J. Allaire in 2009. The software was selected by us because of its data processability and to spare costs. It is available in commercial editions or in open source and it runs on the desktop (Windows, Mac, and Linux) or in a browser connected to RStudio Server. RStudio also has capabilities for using other tools such as C++, CSS, JavaScript and a few other programming languages [61].

Its mission is to build a sustainable open-source business that creates software for data science and statistical computing.

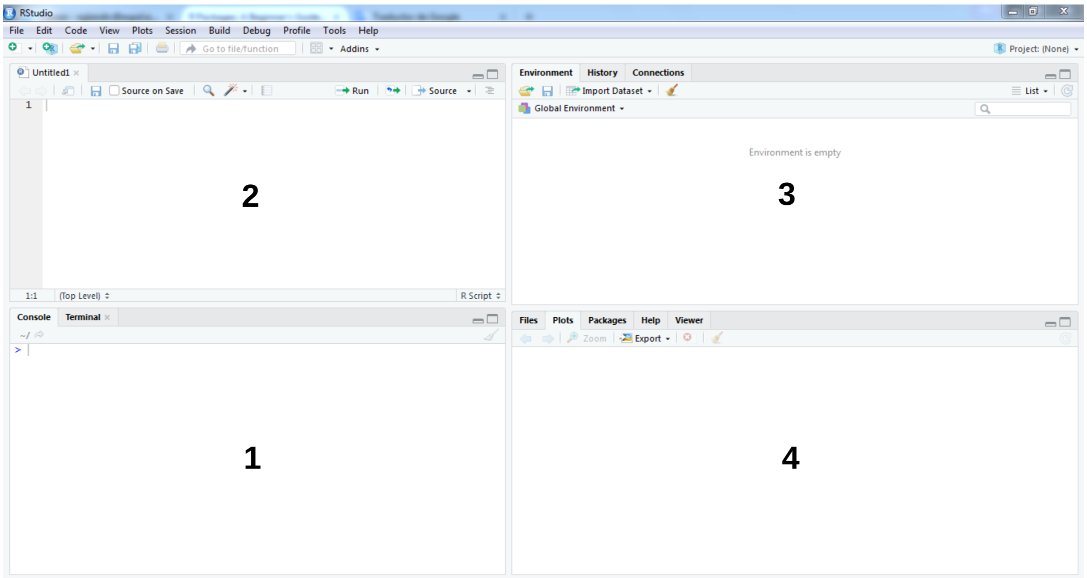


FIGURE 14. RSTUDIO GENERAL OVERVIEW. SOURCE: RSTUDIO.

RStudio overview: Its interface includes a console, syntax-highlighting editor that supports direct code execution, as well as tools for plotting, history, debugging and workspace management, as it is explained in figure 14

1. The **Console** interactively run R commands (Figure 15)

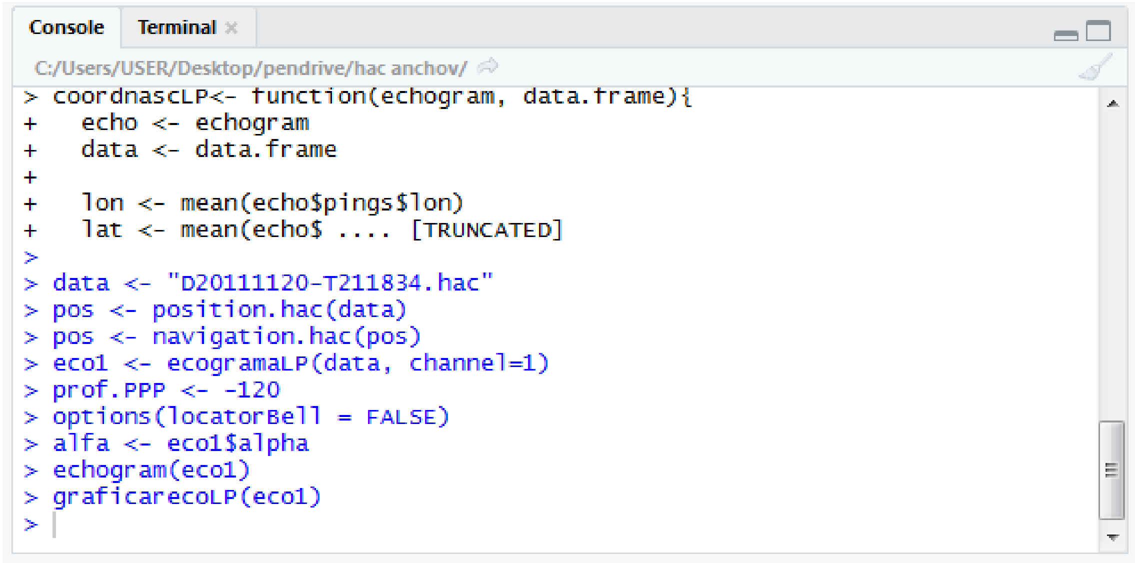


FIGURE 15. CONSOLE RSTUDIO. SOURCE: RSTUDIO.

2. **Source editor** for writing R scripts (Figure 16)

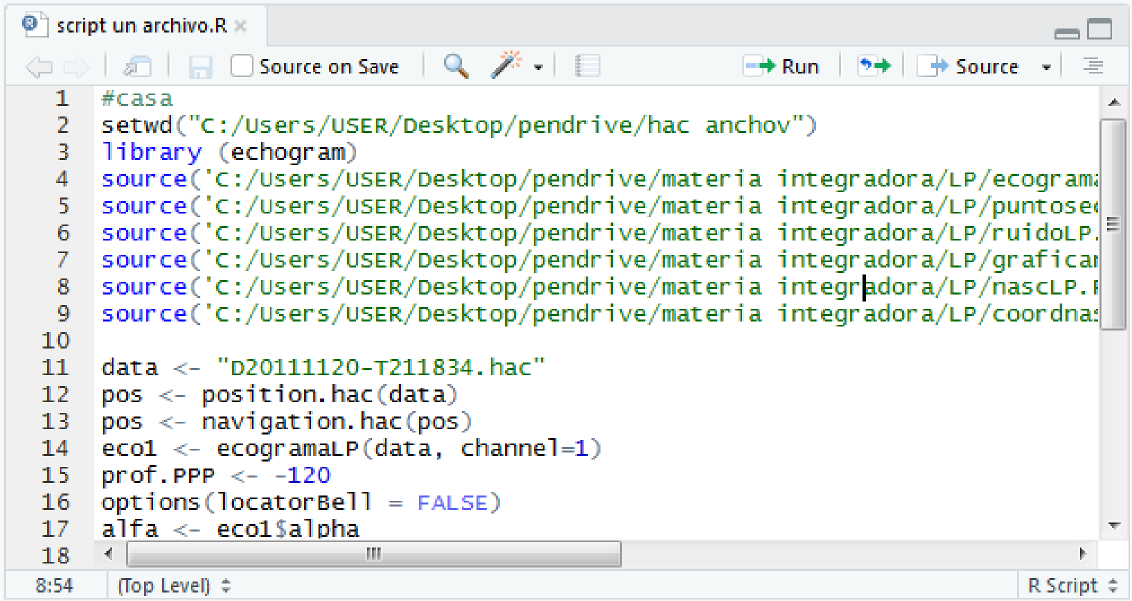


FIGURE 16. SOURCE EDITOR OF RSTUDIO. SOURCE: RSTUDIO.

3. **Workspace** (Figure 17)

a. Environment to view objects in the global environment

b. History to search command history

c. Data viewer for inspecting datasets (Figure 18)

a **b**

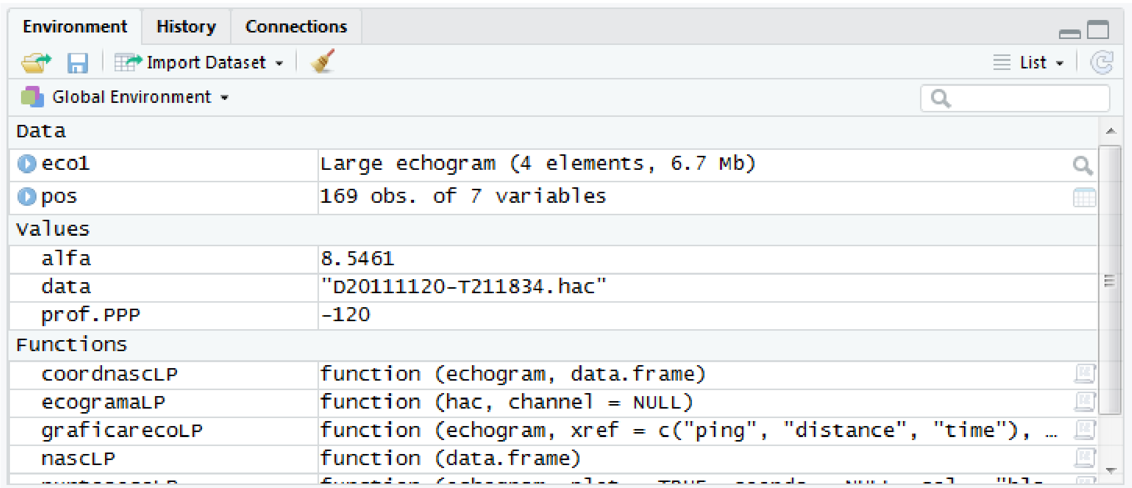


FIGURE 17. WORKSPACE RSTUDIO. SOURCE: RSTUDIO.

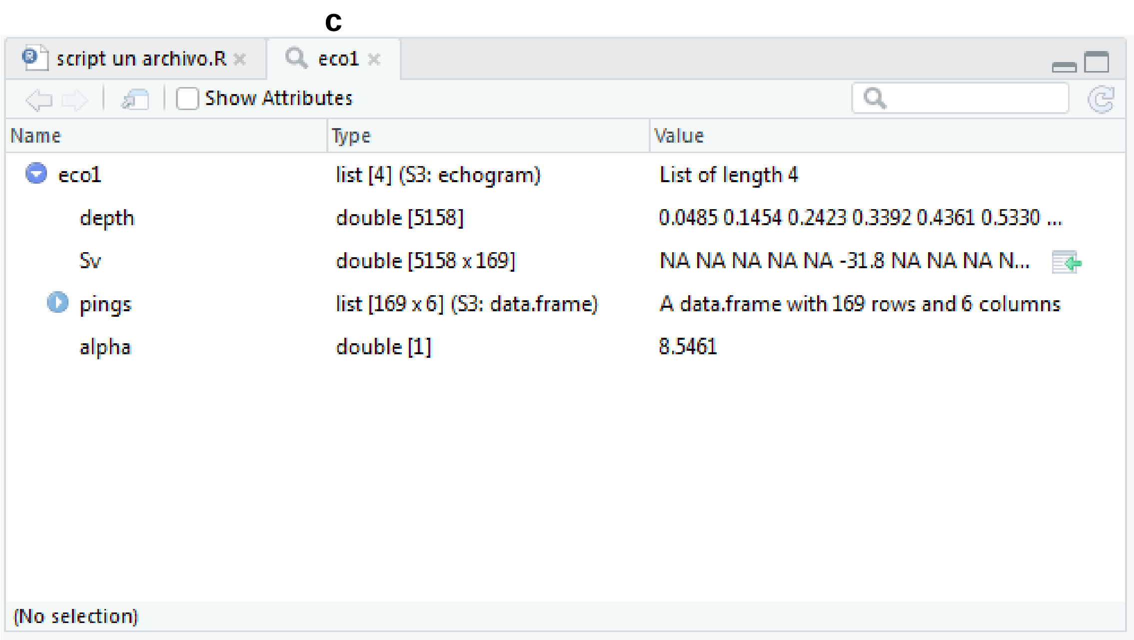


FIGURE 18. DATASETS INSPECTION RSTUDIO. SOURCE: RSTUDIO.

4. **Plot pane** (Figure 19)

d. Dedicated plots pane

e. R package manager

f. Integrated R help

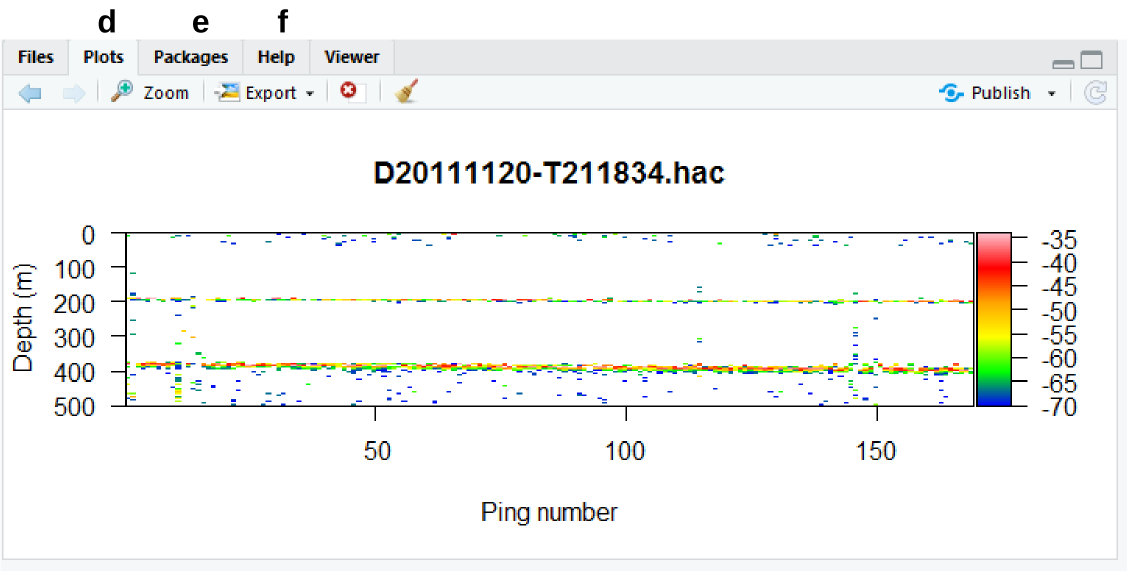


FIGURE 19. PLOT PANE RSTUDIO. SOURCE: RSTUDIO.

Finally we describe another important definition: CRAN *The comprehensive R archive network* is the R official repository in 2017which reached 10,000 published packages approximately [62] for all kind of applications. R packages are collections of functions and data sets developed by the community. They increase the power of R by improving existing base R functionalities, or by adding new ones. We found all the packages that we use and need for the project develop on this repository.

CHAPTER 3

3. SCRIPT DESCRIPTION AND METHODOLOGY

In order to have a better understanding of the client's requirements we were trained by INP's technicians in underwater acoustic science. We also improved our skills in R coding by checking the different functions in its library that could be useful to us.

After that stage, we ran multiple tests in "RStudio" to check the *echogram* package functionality. For these tests we used files from SIMRAD EK60 scientific echo sounder aboard INP's investigation vessel TOHALLI. As a result, the *echogram* package was chosen as the most suitable baseline for this project.

These steps led to the script development, adjusting it to Ecuadorian small pelagic resources conditions and client's needs. We named the script "LandPons" (LP for short). Our project is useful for both approaches: Small pelagic fish and future research surveys. This chapter describes in detail the structure of LP script and its adaptations

3.1. LP Script development

LP script consists of three parts: working directory/loading functions, echogram processing and data input for species biomass and abundance estimation. We explain each part of the code with screenshots from the "RStudio" platform including results of echogram visualization.

In the first part the user sets the working directory which contains the HAC files to process. The next step is to load the *echogram* library as well as the necessary functions to run LP script. The source of the functions must be written according to their location in the computer where LP script is being executed.

```
>#Primera parte: establecer directorio y rutas de trabajo
>setwd("C:/Users/USER/Desktop/pendrive")
> library (echogram)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
ecogramaLP.R', echo=TRUE)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
puntosecoLP.R', echo=TRUE)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
ruidoLP.R', echo=TRUE)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
graficarecoLP.R', echo=TRUE)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
nascLP.R', echo=TRUE)
> source('C:/Users/USER/Desktop/pendrive/materia integradora/LP/
coordnascLP.R', echo=TRUE)
```

Nextly the main procedure will load, read, save and execute functions for the post-processing of echogram data. It follows the sequence below:

1. Produces a character vector of the file names of files or directories in the named directory.
2. Sets the length of the vector
3. Defines constants (length of HAC files in the working directory, depth of interest, alpha which is the absorption coefficient obtained from the HAC file).

```
> #Segunda parte : procesamiento de ecogramas
> hacs <- list.files(pattern=glob2rx("*.hac"))
> nf <- length(hacs)
> prof.PPP <- -120
> options(locatorBell = FALSE)
>   e <- ecogramaLP(hacs[1])
>     alfa <- e$alpha
>     rm(e)
>    f <- matrix(nrow=nf,ncol=3,dimnames=list(hacs,c("longitud
e","latitude","NASC")))
```

4. For loop is in charge of doing the echogram data processing. First, it reads the file name to save it into the variable "data".

```
> for ( k in 1:nf){
>   data <- hacs[k]
```

5. The function *ecogramaLP* reads the file and sets the frequency in KHz, for channel=1 the frequency is 38 KHz and for channel=2 the frequency is 120 KHz, saving it into the variable "z" (Figure 20).

```
> z <- ecogramaLP(hacs[k], channel=1)
```

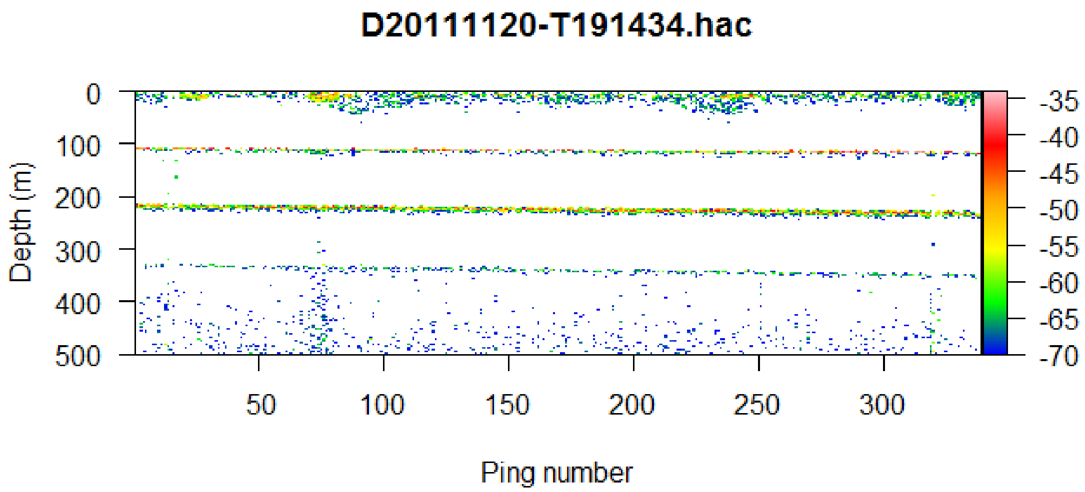


FIGURE 4. RESULTING ECHOGRAM BY PLOTTING Z WITH FUNCTION GRAFICARECOLP. THE NAME OF THE RESPECTIVE FILE WAS SET TO APPEAR AS THE FIGURE TITLE. SOURCE: RSTUDIO.

6. The function *trim.echogram* sets the maximum depth for the echogram visualization as well as the initial ping for z (Figure 21).

```
> z <- trim.echogram(z, depth.max =-prof.PPP, ping.ini = 0)
```

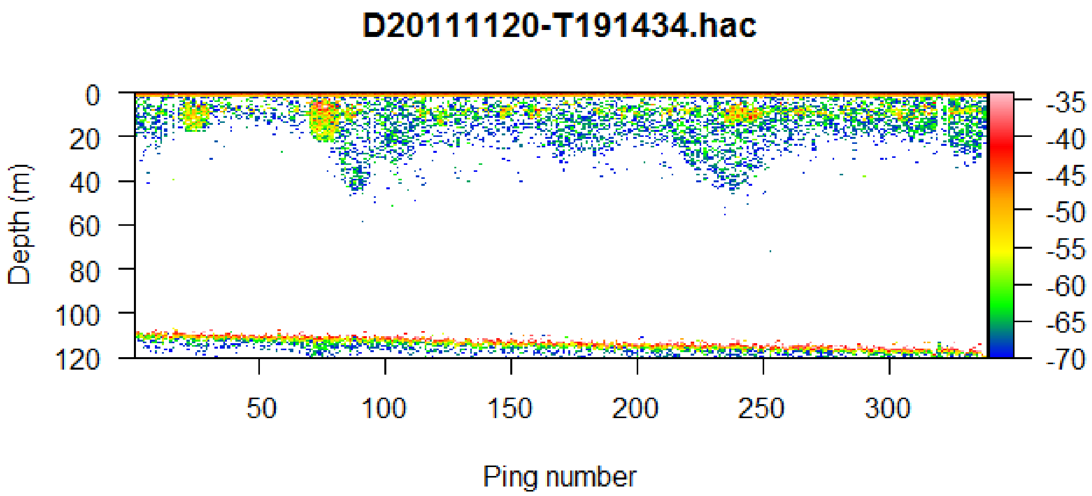


FIGURE 5. RESULTING ECHOGRAM BY PLOTTING Z, IT HAS BEEN TRIMMED WITH FUNCTION TRIM.ECHOGRAM. MAXIMUM DEPTH WAS SET TO 120M DUE TO VISUALIZATION REQUIREMENTS. SOURCE: RSTUDIO.

7. The function *mask.echogram* blanks areas from over the surface and below the bottom applying this to z (Figure22).

```
> z <- mask.echogram(z, surf.off=3, bott.off=0.5, mask=TRUE)
```

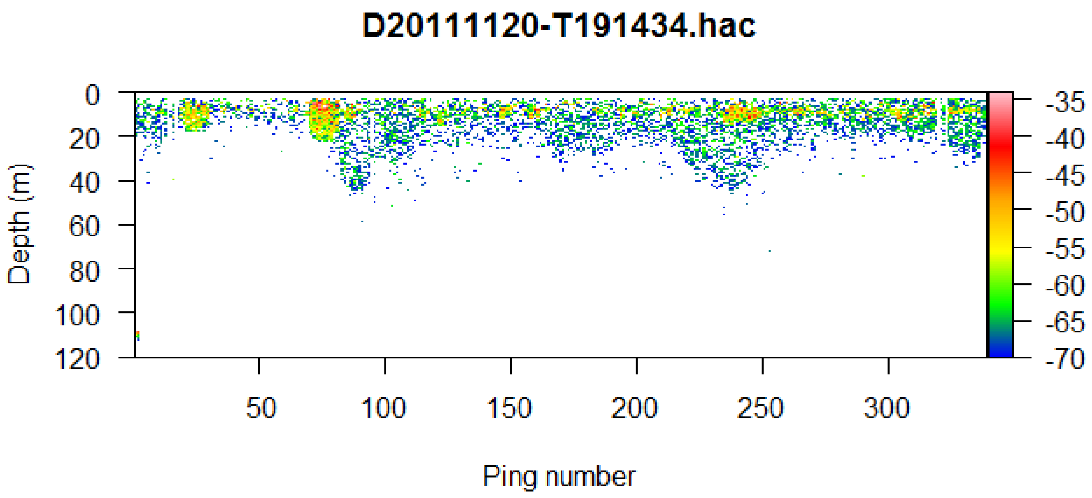


FIGURE 6. RESULTING ECHOGRAM BY PLOTTING Z AFTER APPLYING FUNCTION MASK.ECHOGRAM, SURFACE AND BOTTOM LINES HAVE BEEN REMOVED FROM THE ECHOGRAM AS THEY ARE OF NO INTEREST FOR THE ANALYSIS. SOURCE: RSTUDIO.

The function *ruidoLP* is based on the formulae given by Simmonds and MacLennan to remove background noise and saves it into variable "v" (Figure 23). The red line represents the noise level at 1 m under the transducer's location. This feature could be modified according to the case of study.

```
> v <- ruidoLP(z, ping=50, dB1m=-100, alpha=alfa, out=TRUE, plot=FA
LSE)
```

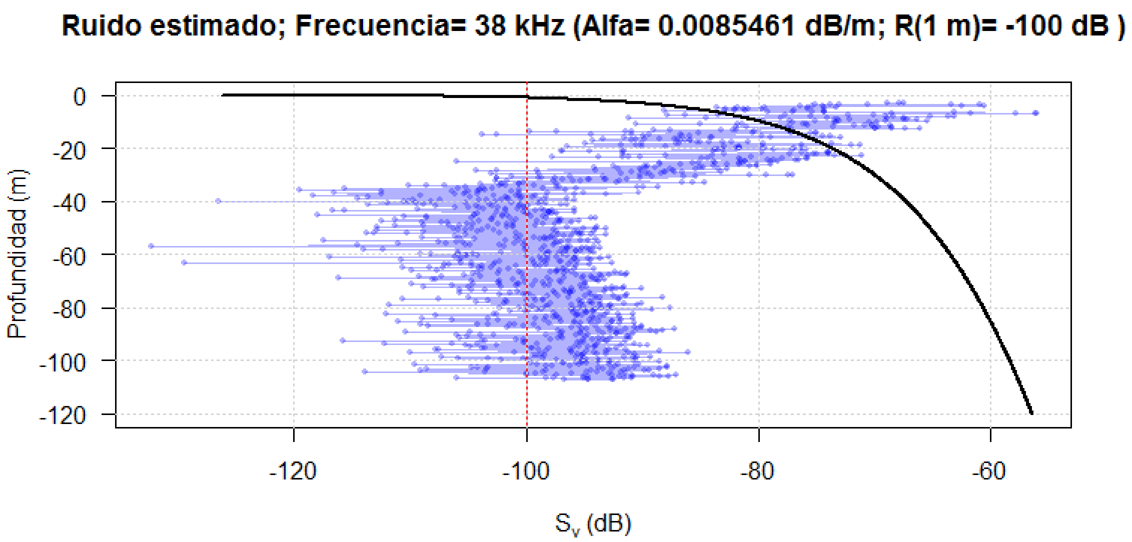


FIGURE 7. ESTIMATED BACKGROUND NOISE (V) PLOT CALCULATED WITH RUIDOLP, SV VALUES IN DECIBELS IN THE X AXIS AND DEPTH IN METERS IN THE Y AXIS. SOURCE: RSTUDIO.

8. The function *add.echogram* makes a mathematical operation between v and z. In this case it subtracts v from z to remove the noise, overwriting it into z (Figure 24).

```
> z <- add.echogram(z, v, operator = "minus", domain="linear")
```

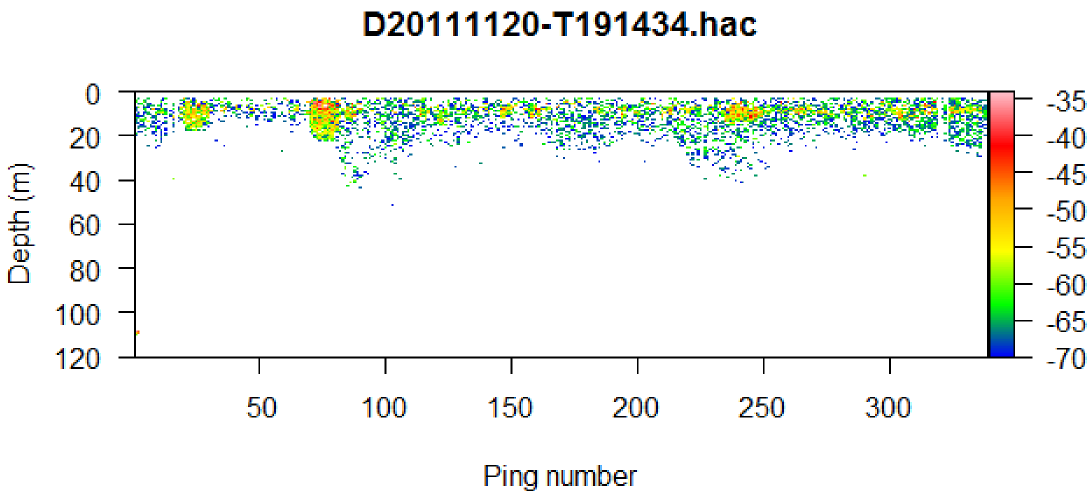


FIGURE 8. ECHOGRAM AFTER NOISE REMOVAL WITH FUNCTION ADD.ECHOGRAM. THIS IS THE FINAL RESULT AFTER THE ECHOGRAM PROCESSING FILTERS. SOURCE: RSTUDIO.

9. The next line of the routine assigns the name to z according to the number of the file.

```
> assign(paste("eco", k, sep="."), z)
```

10. The function *graficarecoLP* plots z as an echogram in which x axis is the number of pings, y axis is depth and z axis is Sv values (Figure#).

```
> graficarecoLP(z)
```

11. The function *puntosecoLP* allows the user to select target points (Figure 25) of "z" by opening a new window saving this information into "u". u is data frame (table 3) that contains the point number, ping coordinates, ping time, longitude, latitude, depth and Sv.

```
> u <- puntosecoLP(z)
```

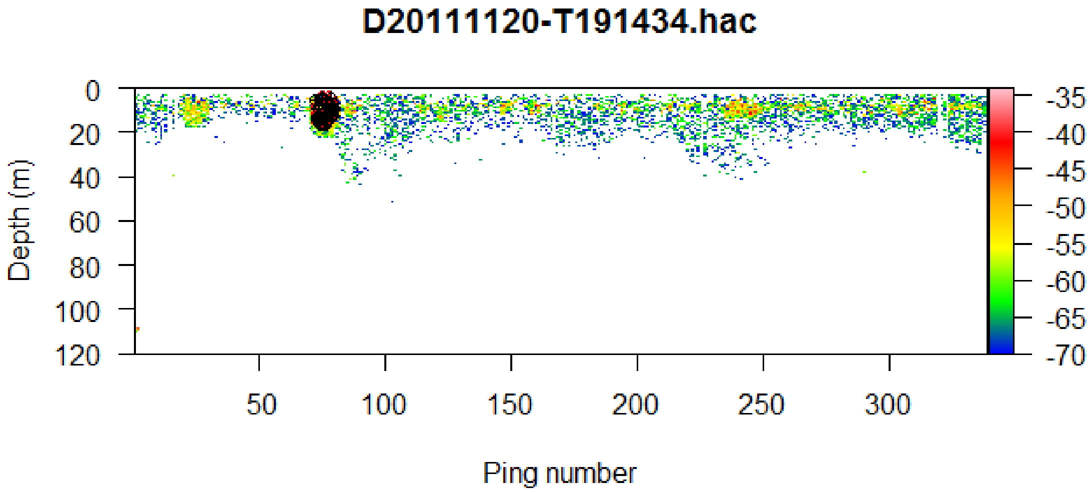


FIGURE 9.RESULTING ECHOGRAM OPENS IN A NEW WINDOW FOR TARGET SELECTION WITH FUNCTION PUNTOSECOLP. SOURCE: RSTUDIO.

	x	y	pingTime	Lon	Lat	Profundidad	Sv
1	72	1180	20/11/2011 19:16:20	-77.72523	-11.57392	5.766454	-37.94009
2	73	1114	20/11/2011 19:16:22	-77.72527	-11.57395	12.162858	-51.84024
3	73	1098	20/11/2011 19:16:22	-77.72527	-11.57395	13.713501	-52.20424
4	74	1073	20/11/2011 19:16:23	-77.72535	-11.574	16.136381	-55.58319
5	76	1073	20/11/2011 19:16:26	-77.72547	-11.57407	16.136381	-62.28868
6	76	1082	20/11/2011 19:16:26	-77.72547	-11.57407	15.264144	-59.66804
7	76	1106	20/11/2011 19:16:26	-77.72547	-11.57407	12.938179	-47.52431
8	76	1114	20/11/2011 19:16:26	-77.72547	-11.57407	12.162858	-53.59534
9	79	1164	20/11/2011 19:16:31	-77.72562	-11.57417	7.317098	-48.32162
10	79	1147	20/11/2011 19:16:31	-77.72562	-11.57417	8.964656	-57.41984
11	76	1180	20/11/2011 19:16:26	-77.72547	-11.57407	5.766454	-50.54167
12	75	1180	20/11/2011 19:16:25	-77.72538	-11.57402	5.766454	-48.14096
13	73	1147	20/11/2011 19:16:22	-77.72527	-11.57395	8.964656	-47.97226
14	73	1106	20/11/2011 19:16:22	-77.72527	-11.57395	12.938179	-51.17999
15	73	1082	20/11/2011 19:16:22	-77.72527	-11.57395	15.264144	-50.63236
16	76	1082	20/11/2011 19:16:26	-77.72547	-11.57407	15.264144	-59.66804
17	77	1082	20/11/2011 19:16:28	-77.7255	-11.57408	15.264144	-58.71897
18	78	1114	20/11/2011 19:16:29	-77.72558	-11.57413	12.162858	-48.32456
19	79	1114	20/11/2011 19:16:31	-77.72562	-11.57417	12.162858	-57.0237
20	79	1131	20/11/2011 19:16:31	-77.72562	-11.57417	10.515299	-66.92911
21	79	1155	20/11/2011 19:16:31	-77.72562	-11.57417	8.189334	-60.28185
22	78	1196	20/11/2011 19:16:29	-77.72558	-11.57413	4.215811	-49.48069
23	75	1196	20/11/2011 19:16:25	-77.72538	-11.57402	4.215811	-38.56006

TABLE 3. DATA FRAME "U" WITH INFORMATION OF 23 POINTS SELECTED WITH FUNCTION PUNTOSECOLP.

12. The next line of the code eliminates the duplicated rows of u. Table 4 contains the results from this line.

```
> u <- u[!duplicated(u),]
```

	x	y	pingTime	Lon	Lat	Profundidad	Sv
1	72	1180	20/11/2011 19:16:20	-77.72523	-11.57392	5.766454	-37.94009
2	73	1114	20/11/2011 19:16:22	-77.72527	-11.57395	12.162858	-51.84024
3	73	1098	20/11/2011 19:16:22	-77.72527	-11.57395	13.713501	-52.20424
4	74	1073	20/11/2011 19:16:23	-77.72535	-11.574	16.136381	-55.58319
5	76	1073	20/11/2011 19:16:26	-77.72547	-11.57407	16.136381	-62.28868
6	76	1082	20/11/2011 19:16:26	-77.72547	-11.57407	15.264144	-59.66804
7	76	1106	20/11/2011 19:16:26	-77.72547	-11.57407	12.938179	-47.52431
8	76	1114	20/11/2011 19:16:26	-77.72547	-11.57407	12.162858	-53.59534
9	79	1164	20/11/2011 19:16:31	-77.72562	-11.57417	7.317098	-48.32162
10	79	1147	20/11/2011 19:16:31	-77.72562	-11.57417	8.964656	-57.41984
11	76	1180	20/11/2011 19:16:26	-77.72547	-11.57407	5.766454	-50.54167
12	75	1180	20/11/2011 19:16:25	-77.72538	-11.57402	5.766454	-48.14096
13	73	1147	20/11/2011 19:16:22	-77.72527	-11.57395	8.964656	-47.97226
14	73	1106	20/11/2011 19:16:22	-77.72527	-11.57395	12.938179	-51.17999
15	73	1082	20/11/2011 19:16:22	-77.72527	-11.57395	15.264144	-50.63236
17	77	1082	20/11/2011 19:16:28	-77.7255	-11.57408	15.264144	-58.71897
18	78	1114	20/11/2011 19:16:29	-77.72558	-11.57413	12.162858	-48.32456
19	79	1114	20/11/2011 19:16:31	-77.72562	-11.57417	12.162858	-57.0237
20	79	1131	20/11/2011 19:16:31	-77.72562	-11.57417	10.515299	-66.92911
21	79	1155	20/11/2011 19:16:31	-77.72562	-11.57417	8.189334	-60.28185
22	78	1196	20/11/2011 19:16:29	-77.72558	-11.57413	4.215811	-49.48069
23	75	1196	20/11/2011 19:16:25	-77.72538	-11.57402	4.215811	-38.56006

TABLE 4. CONTENT OF THE DATA FRAME "U" AFTER APPLYING FUNCTION DUPLICATED. THE POINT #16 WAS REMOVED FROM THE PREVIOUS DATA FRAME SINCE IT WAS DUPLICATED.

13. The function *nascLP* calculates the nautical area scattering coefficient for the group of points with formulae #.#. Where z1 is the maximum depth and z2 is the minimum depth. Now u is a data frame (table 5) with the file name, longitude, latitude, ping time, depth, Sv, mean Sv and NASC.

$$NASC = 4\pi * 1852^2 * (z1 - z2) * 10^{\frac{Sv\ mean}{10}} \quad (3.1)$$

```
> u <- nascLP(u)
```

	x	y	pingTime	Lon	Lat	Profundidad	Sv	NASC	meanNASC
1	72	1180	20/11/2011 19:16:20	-77.72523	-11.57392	5.766454	-37.94009	82561.9001	10332.38
2	73	1114	20/11/2011 19:16:22	-77.72527	-11.57395	12.162858	-51.84024	3363.2913	10332.38
3	73	1098	20/11/2011 19:16:22	-77.72527	-11.57395	13.713501	-52.20424	3092.8923	10332.38
4	74	1073	20/11/2011 19:16:23	-77.72535	-11.574	16.136381	-55.58319	1420.5922	10332.38
5	76	1073	20/11/2011 19:16:26	-77.72547	-11.57407	16.136381	-62.28868	303.3335	10332.38
6	76	1082	20/11/2011 19:16:26	-77.72547	-11.57407	15.264144	-59.66804	554.6064	10332.38
7	76	1106	20/11/2011 19:16:26	-77.72547	-11.57407	12.938179	-47.52431	9085.6951	10332.38
8	76	1114	20/11/2011 19:16:26	-77.72547	-11.57407	12.162858	-53.59534	2245.2012	10332.38
9	79	1164	20/11/2011 19:16:31	-77.72562	-11.57417	7.317098	-48.32162	7561.8299	10332.38
10	79	1147	20/11/2011 19:16:31	-77.72562	-11.57417	8.964656	-57.41984	930.6904	10332.38
11	76	1180	20/11/2011 19:16:26	-77.72547	-11.57407	5.766454	-50.54167	4535.4687	10332.38
12	75	1180	20/11/2011 19:16:25	-77.72538	-11.57402	5.766454	-48.14096	7883.0257	10332.38
13	73	1147	20/11/2011 19:16:22	-77.72527	-11.57395	8.964656	-47.97226	8195.2671	10332.38
14	73	1106	20/11/2011 19:16:22	-77.72527	-11.57395	12.938179	-51.17999	3915.5262	10332.38
15	73	1082	20/11/2011 19:16:22	-77.72527	-11.57395	15.264144	-50.63236	4441.7338	10332.38
17	77	1082	20/11/2011 19:16:28	-77.7255	-11.57408	15.264144	-58.71897	690.0682	10332.38
18	78	1114	20/11/2011 19:16:29	-77.72558	-11.57413	12.162858	-48.32456	7556.7078	10332.38
19	79	1114	20/11/2011 19:16:31	-77.72562	-11.57417	12.162858	-57.0237	1019.5744	10332.38
20	79	1131	20/11/2011 19:16:31	-77.72562	-11.57417	10.515299	-66.92911	104.2025	10332.38
21	79	1155	20/11/2011 19:16:31	-77.72562	-11.57417	8.189334	-60.28185	481.5079	10332.38
22	78	1196	20/11/2011 19:16:29	-77.72558	-11.57413	4.215811	-49.48069	5790.5455	10332.38
23	75	1196	20/11/2011 19:16:25	-77.72538	-11.57402	4.215811	-38.56006	71578.6042	10332.38

TABLE 5. CONTENT OF THE DATA FRAME "U" AFTER APPLYING FUNCTION NASCLP. COLUMNS NASC AND MEANNASC HAVE BEEN ADDED AS A RESULT OF THE FUNCTION.

14. Then the code orders u by ping time. Also it adds a column containing the row number and assigns the name "pts" with the number of file (table 6).

```
> u <- u[order(u$pingTime), ]
> id <- c(1:nrow(u))
> u <- cbind(id,u)
> assign(paste("pts", k, sep="."), u)
```

id	x	y	pingTime	Lon	Lat	Profundidad	Sv	NASC	meanNASC
1	72	1180	20/11/2011 19:16:20	-77.72523	-11.57392	5.766454	-37.94009	82561.9001	10332.38
2	73	1114	20/11/2011 19:16:22	-77.72527	-11.57395	12.162858	-51.84024	3363.2913	10332.38
3	73	1098	20/11/2011 19:16:22	-77.72527	-11.57395	13.713501	-52.20424	3092.8923	10332.38
4	73	1147	20/11/2011 19:16:22	-77.72527	-11.57395	8.964656	-47.97226	8195.2671	10332.38
5	73	1106	20/11/2011 19:16:22	-77.72527	-11.57395	12.938179	-51.17999	3915.5262	10332.38
6	73	1082	20/11/2011 19:16:22	-77.72527	-11.57395	15.264144	-50.63236	4441.7338	10332.38
7	74	1073	20/11/2011 19:16:23	-77.72535	-11.574	16.136381	-55.58319	1420.5922	10332.38
8	75	1180	20/11/2011 19:16:25	-77.72538	-11.57402	5.766454	-48.14096	7883.0257	10332.38
9	75	1196	20/11/2011 19:16:25	-77.72538	-11.57402	4.215811	-38.56006	71578.6042	10332.38
10	76	1073	20/11/2011 19:16:26	-77.72547	-11.57407	16.136381	-62.28868	303.3335	10332.38
11	76	1082	20/11/2011 19:16:26	-77.72547	-11.57407	15.264144	-59.66804	554.6064	10332.38
12	76	1106	20/11/2011 19:16:26	-77.72547	-11.57407	12.938179	-47.52431	9085.6951	10332.38
13	76	1114	20/11/2011 19:16:26	-77.72547	-11.57407	12.162858	-53.59534	2245.2012	10332.38
14	76	1180	20/11/2011 19:16:26	-77.72547	-11.57407	5.766454	-50.54167	4535.4687	10332.38
15	77	1082	20/11/2011 19:16:28	-77.7255	-11.57408	15.264144	-58.71897	690.0682	10332.38
16	78	1114	20/11/2011 19:16:29	-77.72558	-11.57413	12.162858	-48.32456	7556.7078	10332.38
17	78	1196	20/11/2011 19:16:29	-77.72558	-11.57413	4.215811	-49.48069	5790.5455	10332.38
18	79	1164	20/11/2011 19:16:31	-77.72562	-11.57417	7.317098	-48.32162	7561.8299	10332.38
19	79	1147	20/11/2011 19:16:31	-77.72562	-11.57417	8.964656	-57.41984	930.6904	10332.38
20	79	1114	20/11/2011 19:16:31	-77.72562	-11.57417	12.162858	-57.0237	1019.5744	10332.38
21	79	1131	20/11/2011 19:16:31	-77.72562	-11.57417	10.515299	-66.92911	104.2025	10332.38
22	79	1155	20/11/2011 19:16:31	-77.72562	-11.57417	8.189334	-60.28185	481.5079	10332.38

TABLE 6. CONTENT OF THE DATA FRAME "U" ORDERED BY PINGTIME (SECONDS DIFFERENCE) AND WITH ID COLUMN.

15. Finally, the function *coordnascLP* calculates mean longitude, mean latitude, and extracts mean NASC from u data frame. The answer is a matrix with this three fields saving it to "r" (table 7).The for loop continues until all the files in the directory are processed, the final answer is matrix "f.

```
> r <- coordnascLP(z,u)
> f[k,]<-r
  }
```

	longitude	latitude	NASC
D20111120-T191434.hac	-77.73096	-11.57739	10332.38

TABLE 7. CONTENT OF MATRIX F (1X3). IN THIS CASE, THE NUMBER OF ROWS IS 1 (K) BECAUSE THE SCRIPT WAS RUN FOR ONLY 1 HAC FILE, IT IS ALSO ADDED THE FILE NAME IN THE FIRST COLUMN.

The third part of the routine creates a matrix that contains the resulting matrix "f" along with the species frequencies. The user needs to fill up the matrix with species frequencies after the exploratory fishing from the hydroacoustic survey. After that input, the code saves the information into "j".

```
> #Tercera Parte
> j<-matrix(nrow=nf,ncol=5, dimnames=list(c(1:nf),c("f.macarela","f.bo
tella","f.picudillo","f.pinchagua","f.otros")))
> write.csv(j, file=paste("Frecuencias", "csv", sep="."))
> j <- read.csv("Frecuencias.csv", header=TRUE, sep=",", dec=".")
```

Then each frequency from j is multiplied by i (the NASC column of “f”) and by 0.01 overwriting the result in “j” (table 8).

```
> i <-as.vector(f[,"NASC"])
> nc <- ncol(j)
> j <- j[,2:nc]*i*0.01
```

Mean value of j is saved in a csv file.

```
> Transectas<-colSums(j, na.rm=TRUE)
> Promedio <- Transectas/nf
> tf <- cbind(f,j)
> write.csv(tf, file=paste("FinalTransect", "csv", sep="."))
```

	longitude	latitude	NASC	f.macarela	f.botella	f.picudillo	f.pinchagua	f.otros
D20111120-T191434.hac	-77.7309589	-11.5773933	10332.3757	9299.13809	0	0	0	516.618783

TABLE 8. FINAL MATRIX NAMED “FINAL TRANSECT”. THE MATRIX CONTAINS THE INFORMATION NEEDED FOR THE BIOMASS AND ABUNDANCE ESTIMATION ONCE IT THE USER MAKES THE INPUT WITH THE EXPLORATORY FISHING DATA.

At the end, the code deletes all the variables that are no longer of interest.

```
> rm(x,y,z,v,u,id,k,nf,alfa,i,prof.PPP,hacs,data,ma,r,j,f,nc)
> rm(list=ls(pattern=glob2rx("pts.*")))
> rm(list=ls(pattern=glob2rx("eco.*")))
```

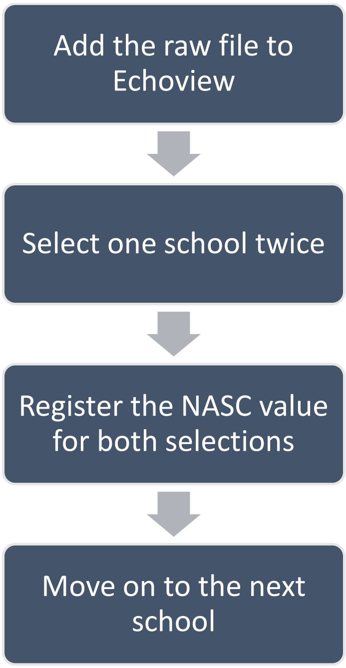
CHAPTER 4

4. VALIDATIONS

In this chapter, we present validations of the LP script. Different methodologies are described for accuracy and precision validation. The first section consists of testing Echoview's accuracy by comparing NASC values for 3 files with more than one school, selecting them twice in the trial version of Echoview. In the second section we compared NASC values for those same files using script LP script. The next section compares NASC values for all total files with both methodologies simultaneously. Finally we determinate the precision of LP script by running 155 files twice obtaining NASC values for each run.

4.1. Echoview Accuracy

We validated Echoview's accuracy comparing NASC values using the trial version of software Echoview. For this purpose, we selected three raw files with two or more school detections following the sequence below for each file:



Results of this comparison are shown in table 7. We obtained a mean value for Echoview's accuracy of 0.031%. It indicates perfect accuracy (0%).

FILE NAME	SCHOOLS	# POINTS	NASC1 (m^2/NM^2)	# POINTS	NASC2 (m^2/NM^2)	ERROR (%)	ROUND ERROR (%)	MEAN ERR (%)
D20111121-T000237	1	350	4223.21	355	4223.27	0.00142072	0.001	0.020
	2	390	5059.19	395	5059.25	0.001185961	0.001	
	3	432	2117.25	438	2117.27	0.000944622	0.001	
	4	609	2016.81	623	2018.04	0.060987401	0.061	
	5	216	530.84	220	531.03	0.035792329	0.036	
D20111121-T235413	1	1218	9067.7	1232	9067.84	0.001543942	0.002	0.002
	2	903	11594.81	910	11595.06	0.002156137	0.002	
D20111121-T002338	1	430	3383.78	435	3394.59	0.319465213	0.319	0.048
	2	405	974.28	395	973.96	0.032844767	0.033	
	3	365	4067.6	370	4067.36	0.005900285	0.006	
	4	268	1135.6	268	1135.6	0	0.000	
	5	395	7373.23	400	7373.32	0.001220632	0.001	
	6	1521	8998.24	1521	8998.24	0	0.000	
	7	864	5441.65	896	5442.63	0.018009244	0.018	
	8	216	4269.34	219	4269.51	0.00398188	0.004	
							TOTAL MEAN	**0.031**

TABLE 9. RESULTS FROM ECHOVIEW ACCURACY.

Additionally, we made column graphs comparing NASC 1 and NASC 2 values for the three files. The minimum error was obtained from file # 2 with 0.002% accuracy. The column graphs are presented below:

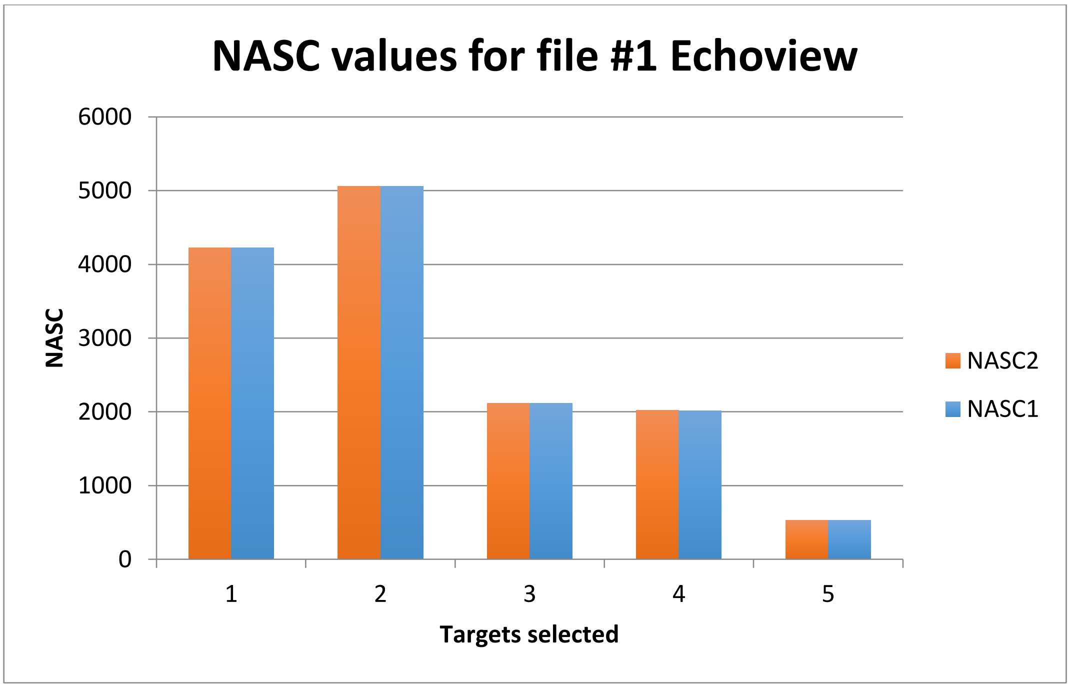


FIGURE 10. ECHOVIEW NASC VALUES FOR THE FIRST FILE.

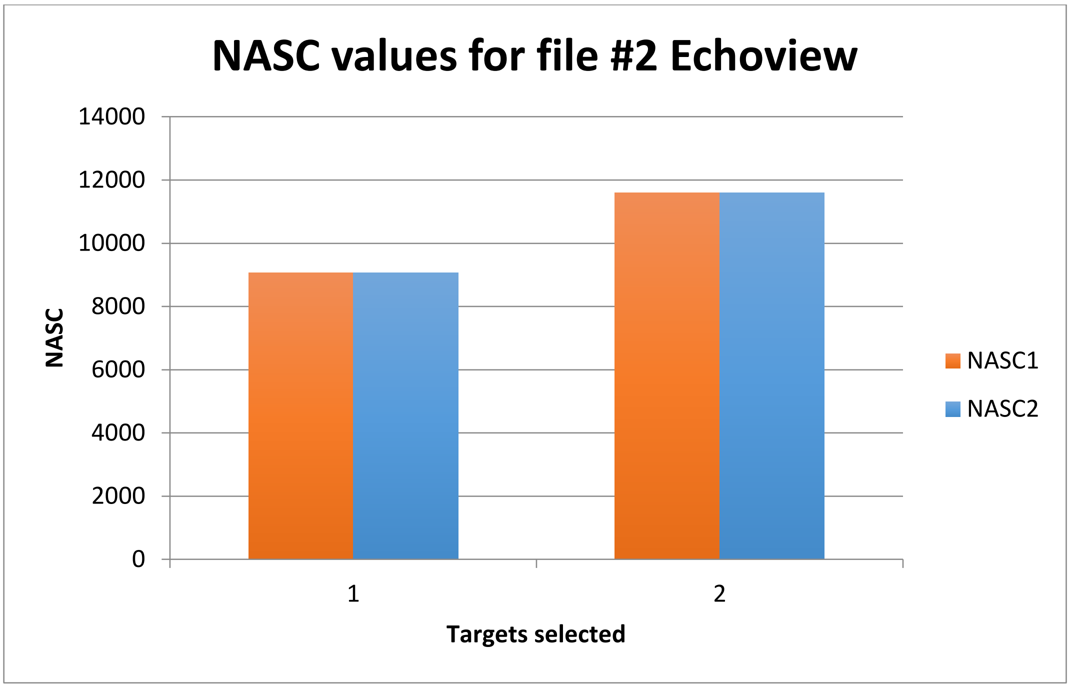


FIGURE 11. ECHOVIEW NASC VALUES FOR THE SECOND FILE.

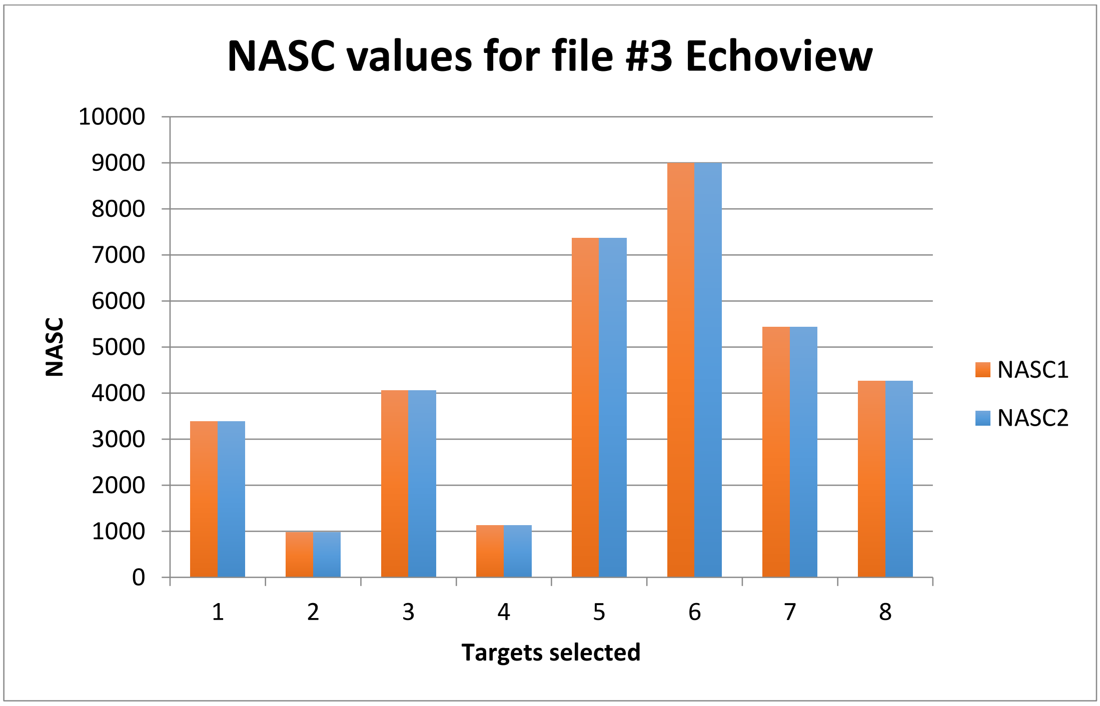
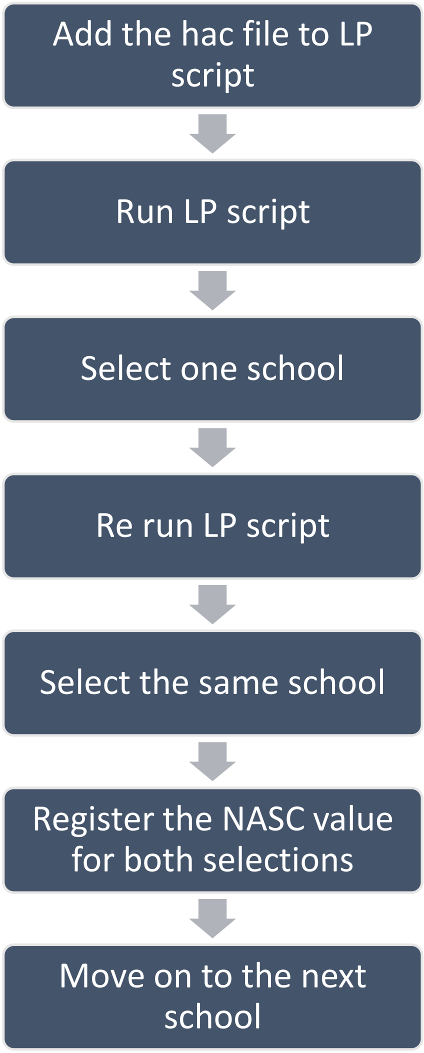


FIGURE 12. ECHOVIEW NASC VALUES FOR THE THIRD FILE.

4.2. LP Accuracy

We validated LP script accuracy using the same files selected in 4.1 following the next sequence:



The results of this comparison are shown in table 8. We obtained a mean value for LP script accuracy of 7.215%. It indicates high accuracy (0-10%).

FILE NAME	SCHOOLS	# POINTS	NASC 1 (m^2/NM^2)	# POINTS	NASC 2 (m^2/NM^2)	ERROR (%)	ROUND ERROR (%)	MEAN ERR (%)
D20111121-T000237	1	104	6042.345	104	5500.1	8.9740821	8.974	**8.489**
	2	89	5971.448	97	6192.412	3.7003420	3.700	
	3	113	3158.781	111	3797.37	20.2163113	20.216	
	4	140	3086.242	140	2851.571	7.6037783	7.604	
	5	64	784.9196	66	800.2443	1.9523910	1.952	
D20111121-T235413	1	278	14165.42	273	12456.23	12.0659324	12.066	**7.991**
	2	187	13286.34	176	13806.76	3.9169553	3.917	

D20111121-T002338	1	130	3942.866	131	3508.417	11.0186093	11.019	5.164
	2	78	1354.753	80	1417.6377	4.6417834	4.642	
	3	111	5044.494	120	4918.251	2.5025900	2.503	
	4	78	1443.283	72	1475.534	2.2345583	2.235	
	5	109	8905.501	103	8450.641	5.1076295	5.108	
	6	365	11609.62	366	13137.1	13.1570198	13.157	
	7	167	8247.227	187	8449.115	2.4479501	2.448	
	8	77	3988.915	68	3980.86	0.2019346	0.202	
							TOTAL MEAN	**7.215**

TABLE 10. RESULTS FROM LP ACCURACY.

Moreover, we also made column graphs comparing NASC 1 and NASC 2 values for the same three files. The minimum error was obtained from file # 3 with 5.164% accuracy. The column graphs are presented below:

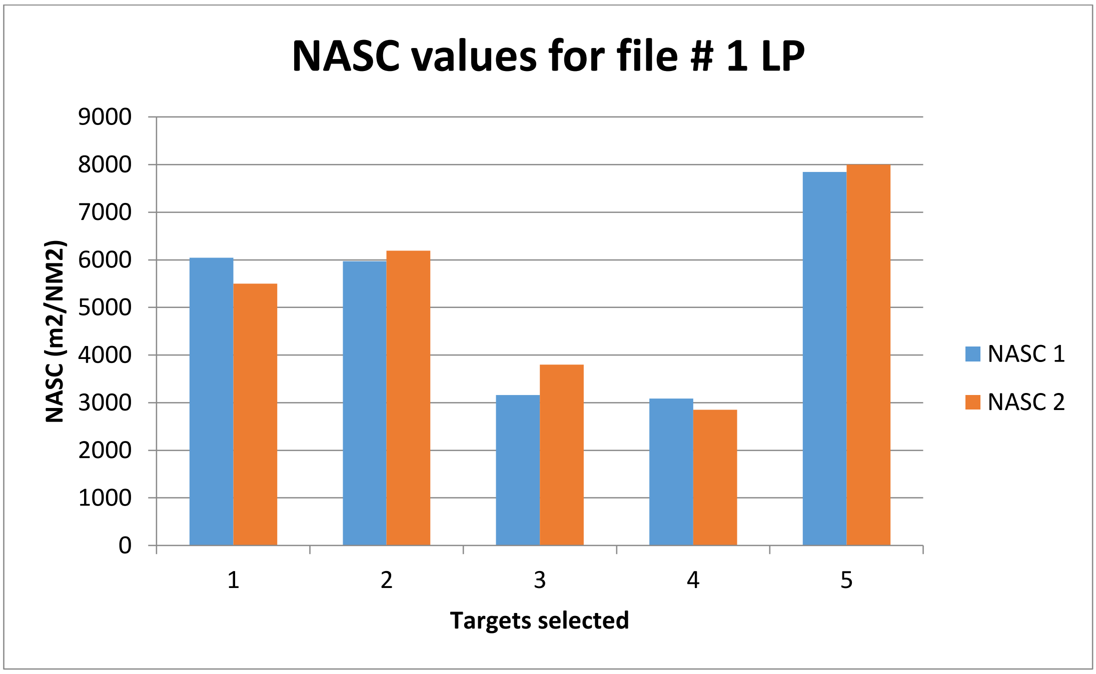


FIGURE 13. LP NASC VALUES FOR THE FIRST FILE.

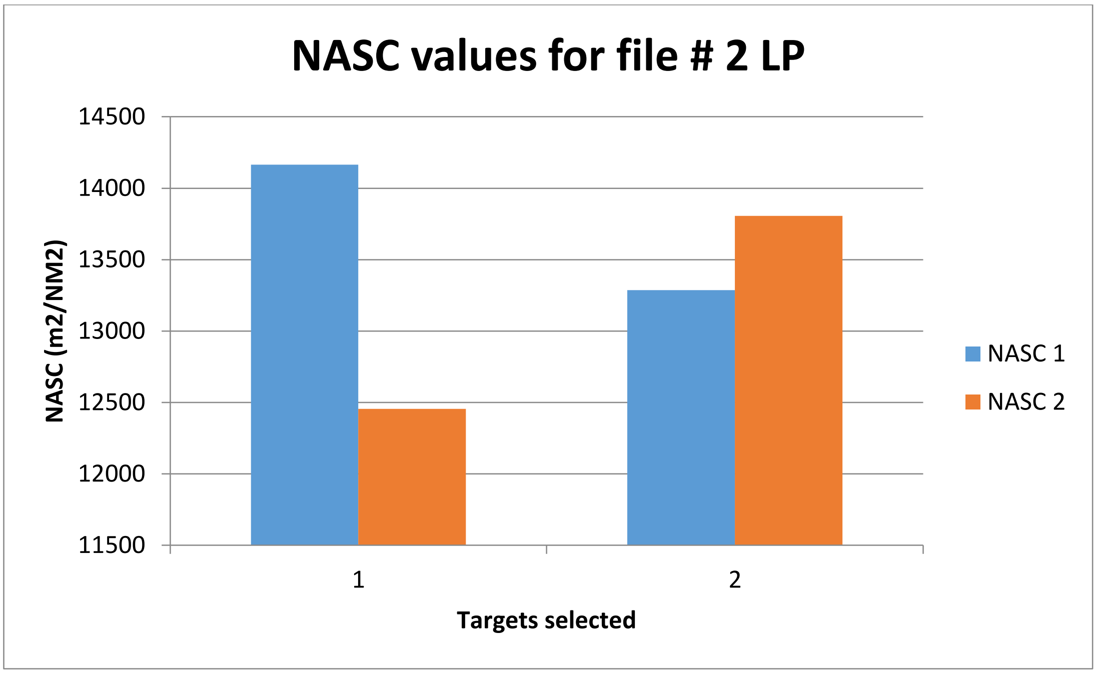


FIGURE 14. LP NASC VALUES FOR THE SECOND FILE.

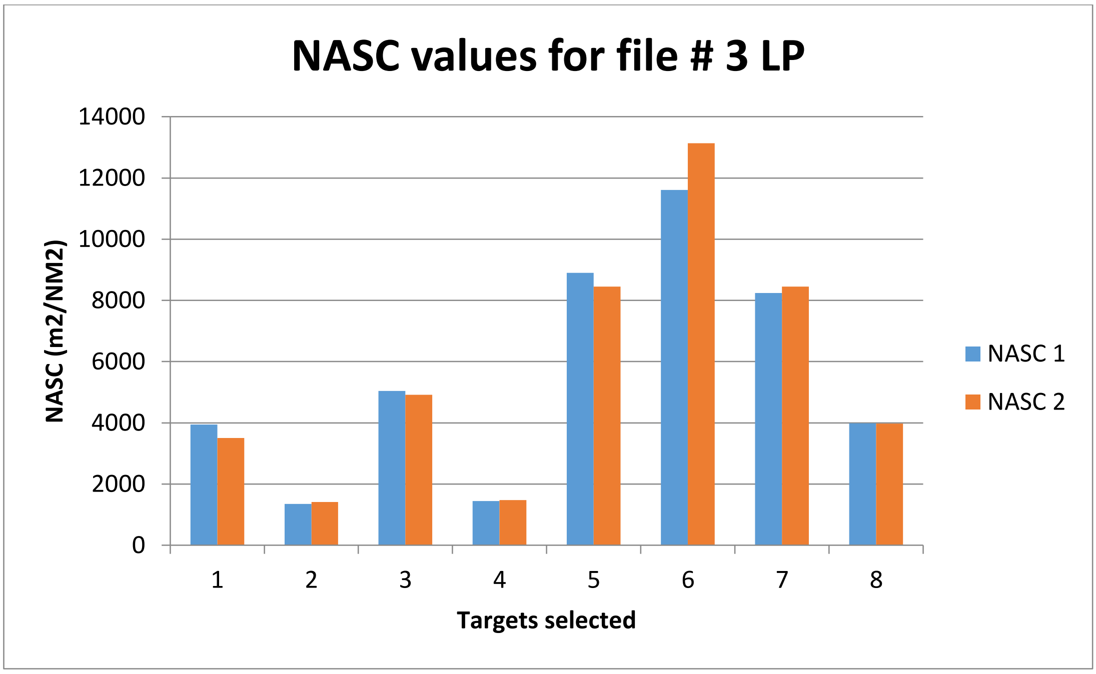


FIGURE 15. LP NASC VALUES FOR THE THIRD FILE.

4.3. Echoview vs R (Accuracy)

We validated the accuracy between Echoview and LP script results. We worked with 156 raw files for Echoview and the respective hac file for LP script. For these tests we used the next methodology simultaneously:

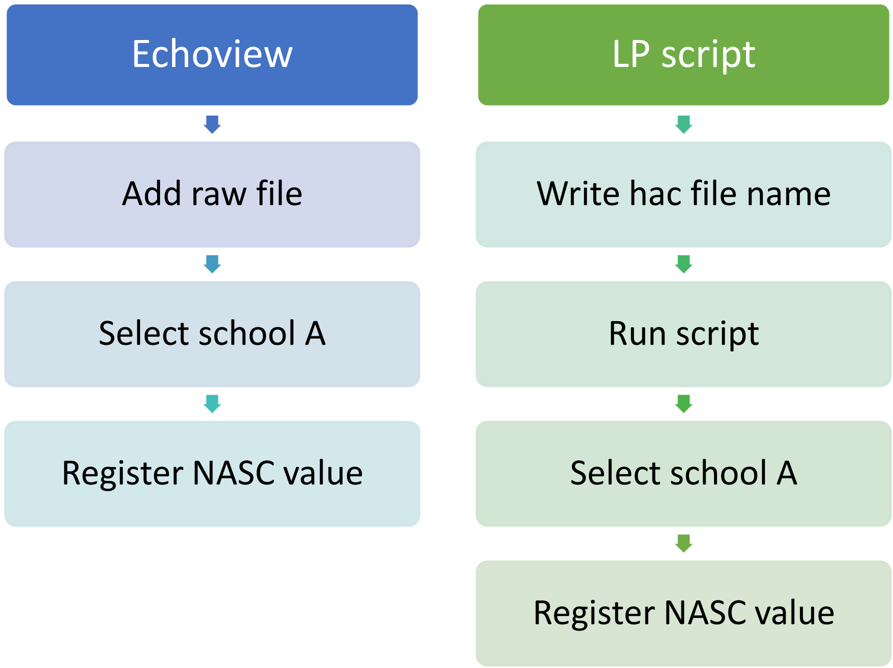


Figure #32 and figure #33 illustrate the NASC values obtained with LP script and Echoview for the same target school. A comparison of Echoview and LP NASC values is on Appendix *ECHOVIEW – LP SCRIPT TABLE OF COMPARISON.* We plotted these results showing a visual comparison in Figure #34.

We made a histogram in order to understand errors obtained. We grouped the 156 files into 8 classes, then we determinate the number of files that belong to each class. The majority of files are located in classes 2 and 3 that represent a range of error between 5-14%. This range contains 49% of the total data (76 out of 156 files).

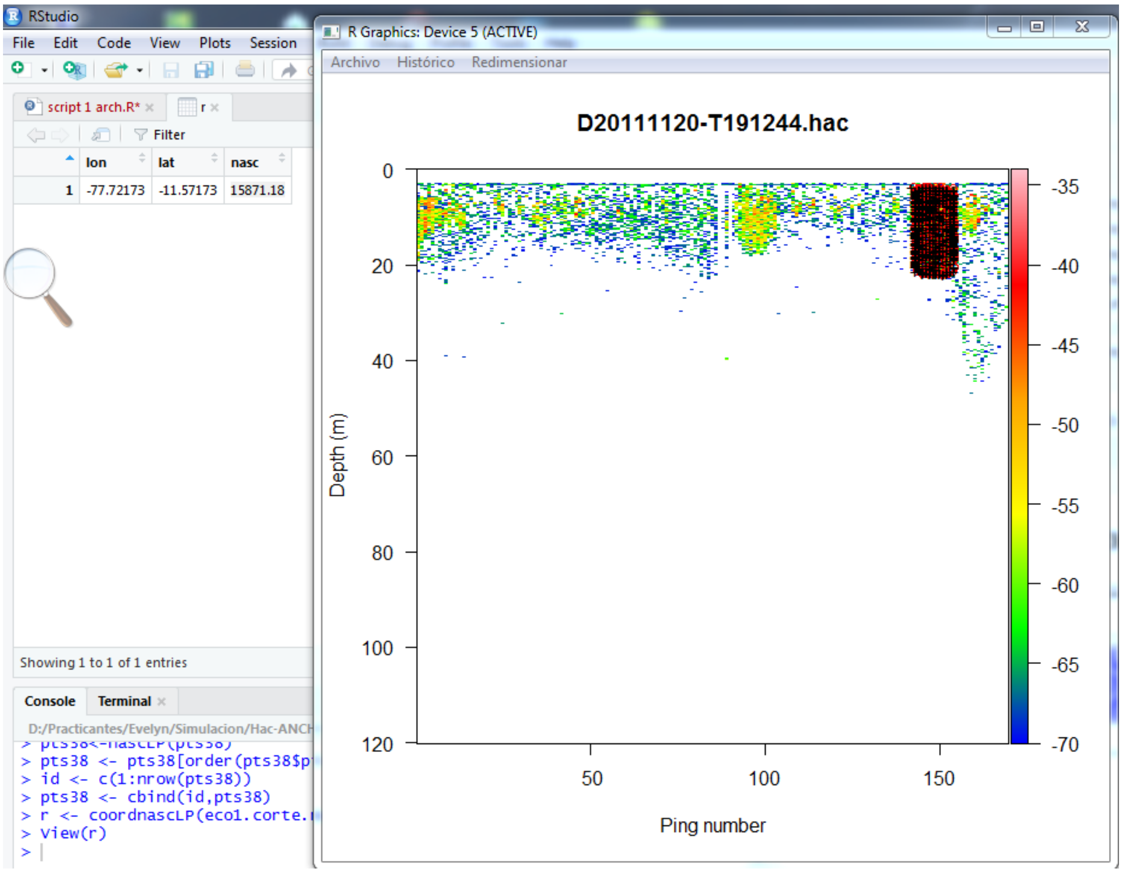


FIGURE 16. TARGET SELECTION WITH LP SCRIPT.

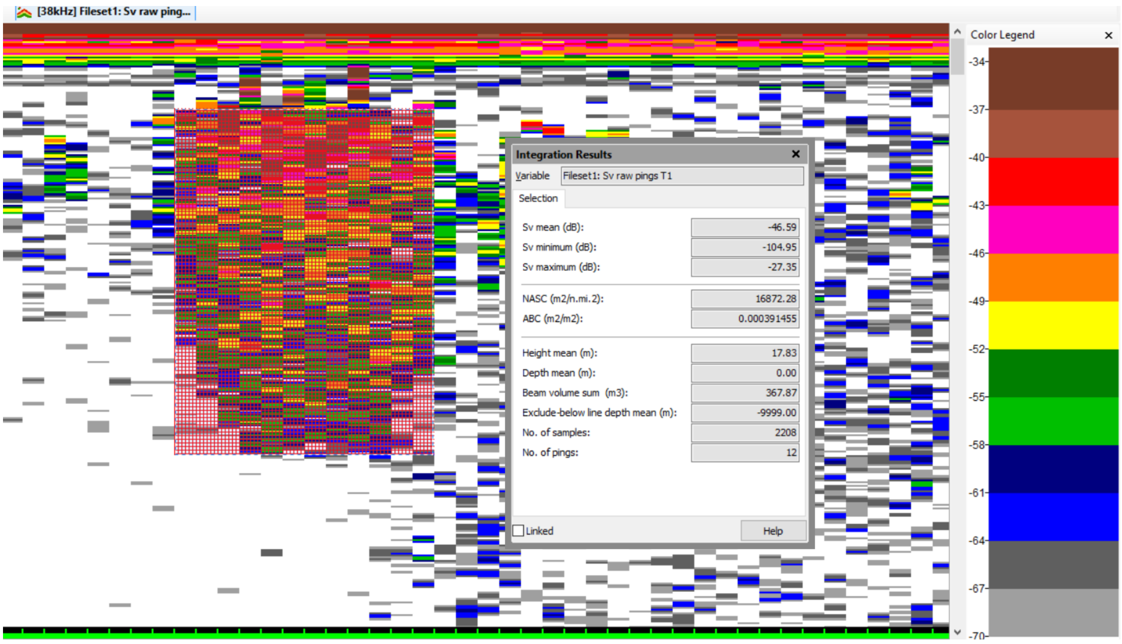


FIGURE 17. TARGET SELECTION WITH ECHOVIEW.

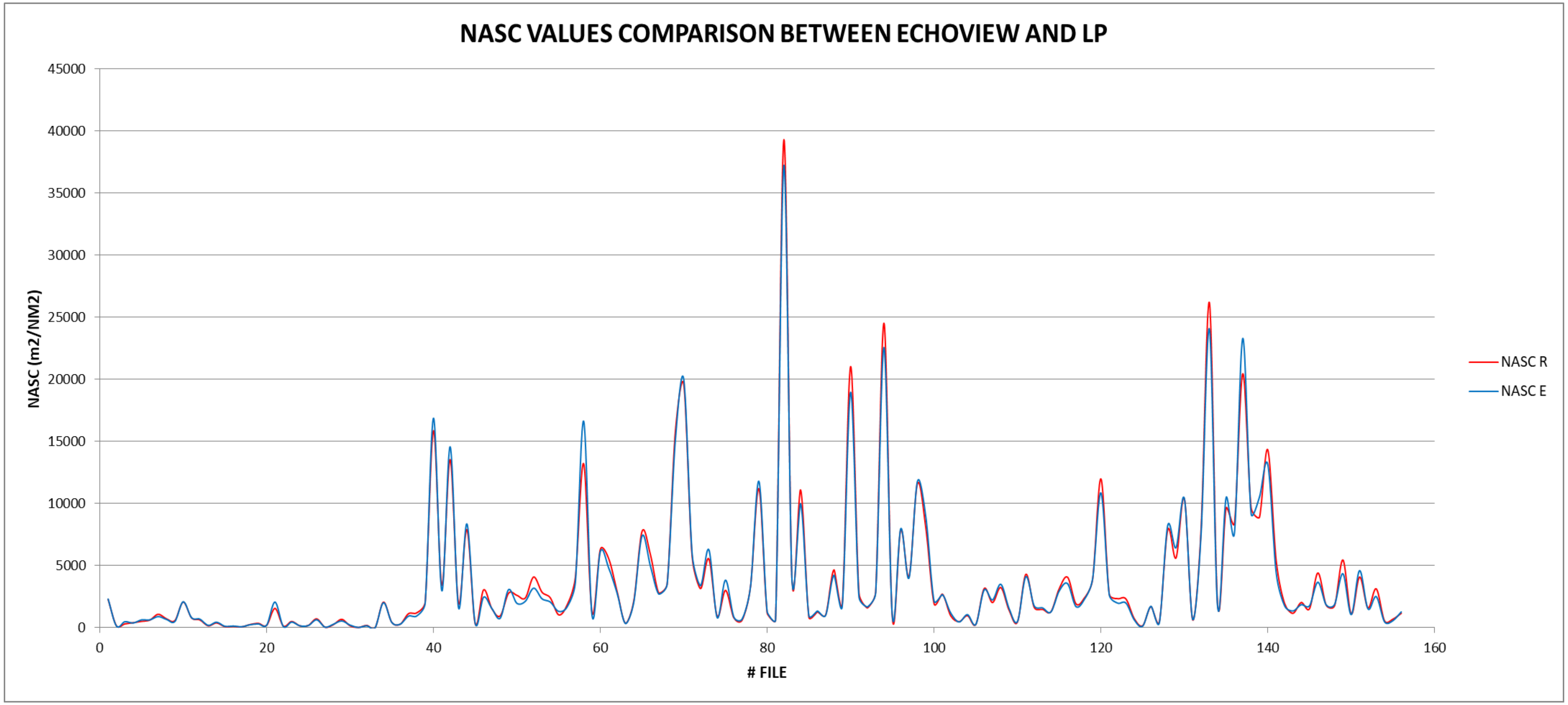


FIGURE 18. NASC VALUES COMPARISON BETWEEN ECHOVIEW AND LP.

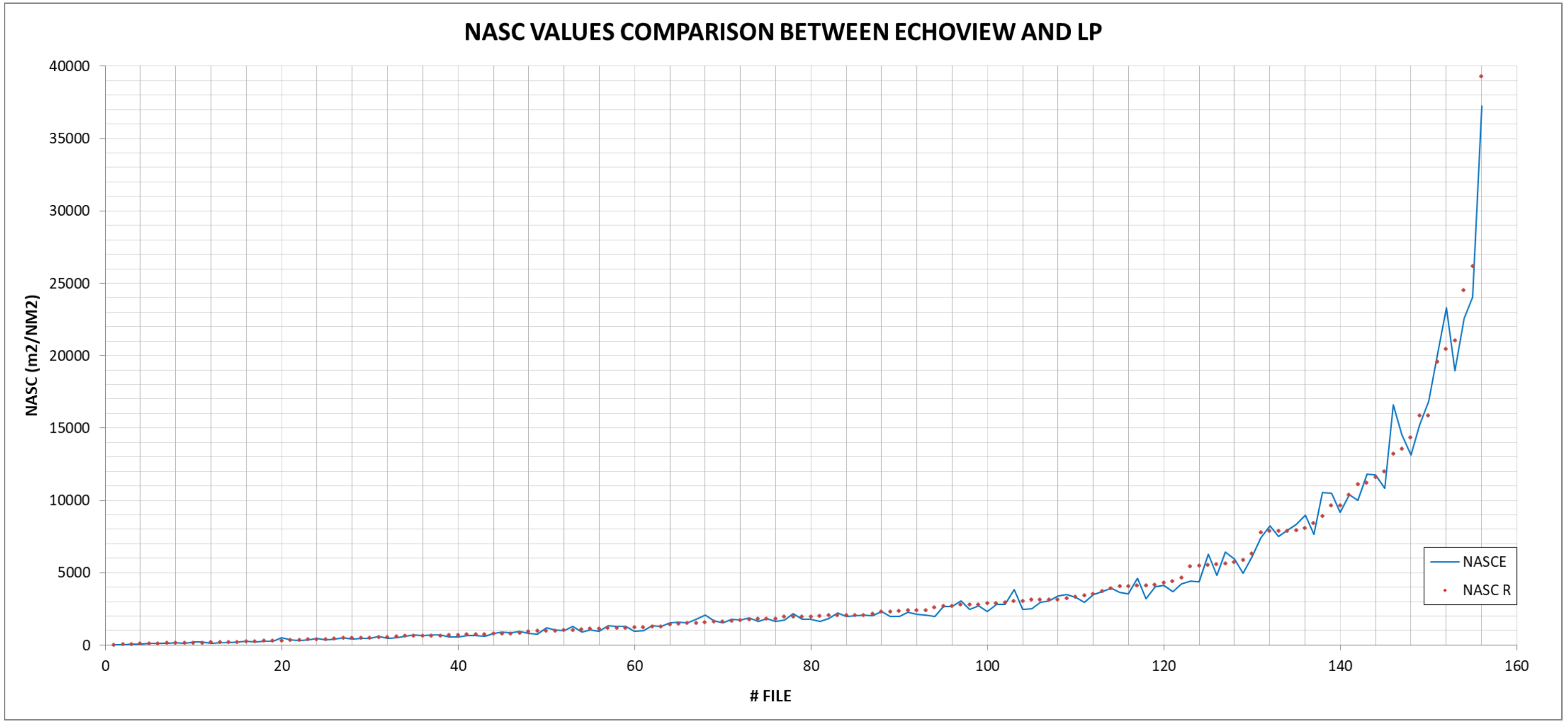


FIGURE 19. NASC VALUES COMPARISON BETWEEN ECHOVIEW AND LP.

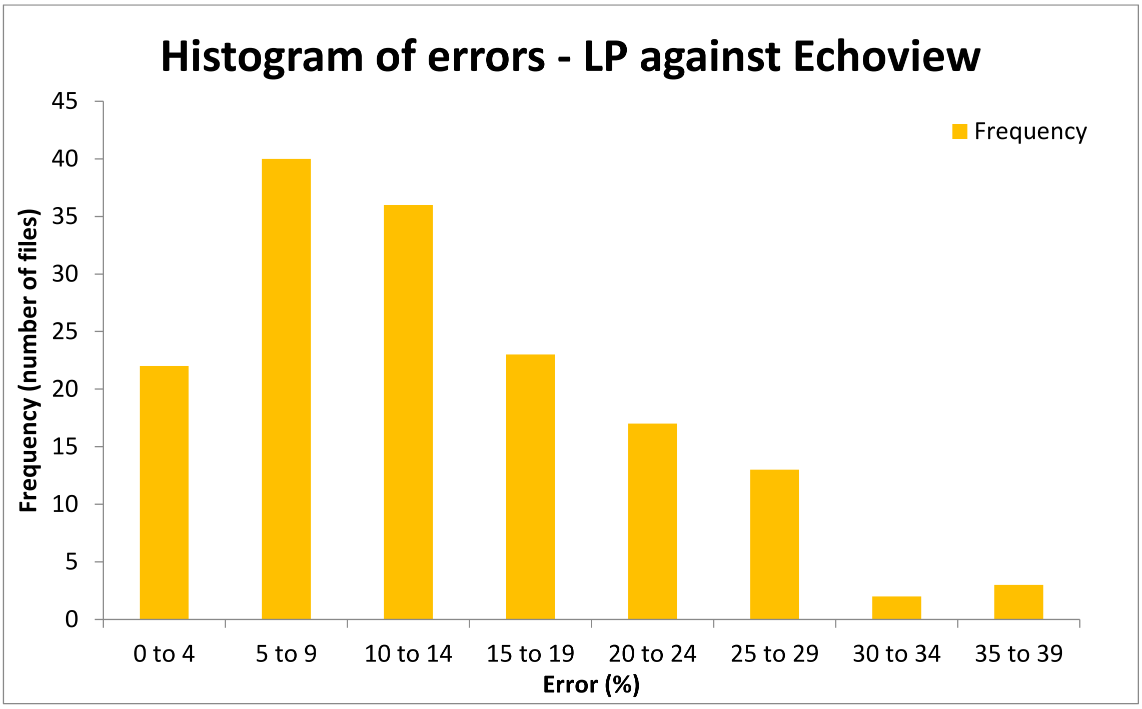


FIGURE 20. HISTOGRAM OF ERROR OBTAINED FROM ECHOVIEW AND LP SCRIPT

4.4. LP vs LP (Precision)

The last step for LP script validation was to determinate its precision. In order to do that we ran LP script for the 155 hac files twice. We registered the NASC values in a table that is on Appendix *LP SCRIPT NASC VALUES TABLE OF COMPARISON*. We plotted the results for a visual comparison in figure #37.

To determinate the number of files that represent the majority of error, we made a histogram grouping 155 files into 8 classes. The majority of errors are located in classes 1 and 2 that represent a range between 0 - 11%. This range contains 57% of the total data (89 out of 155 files).

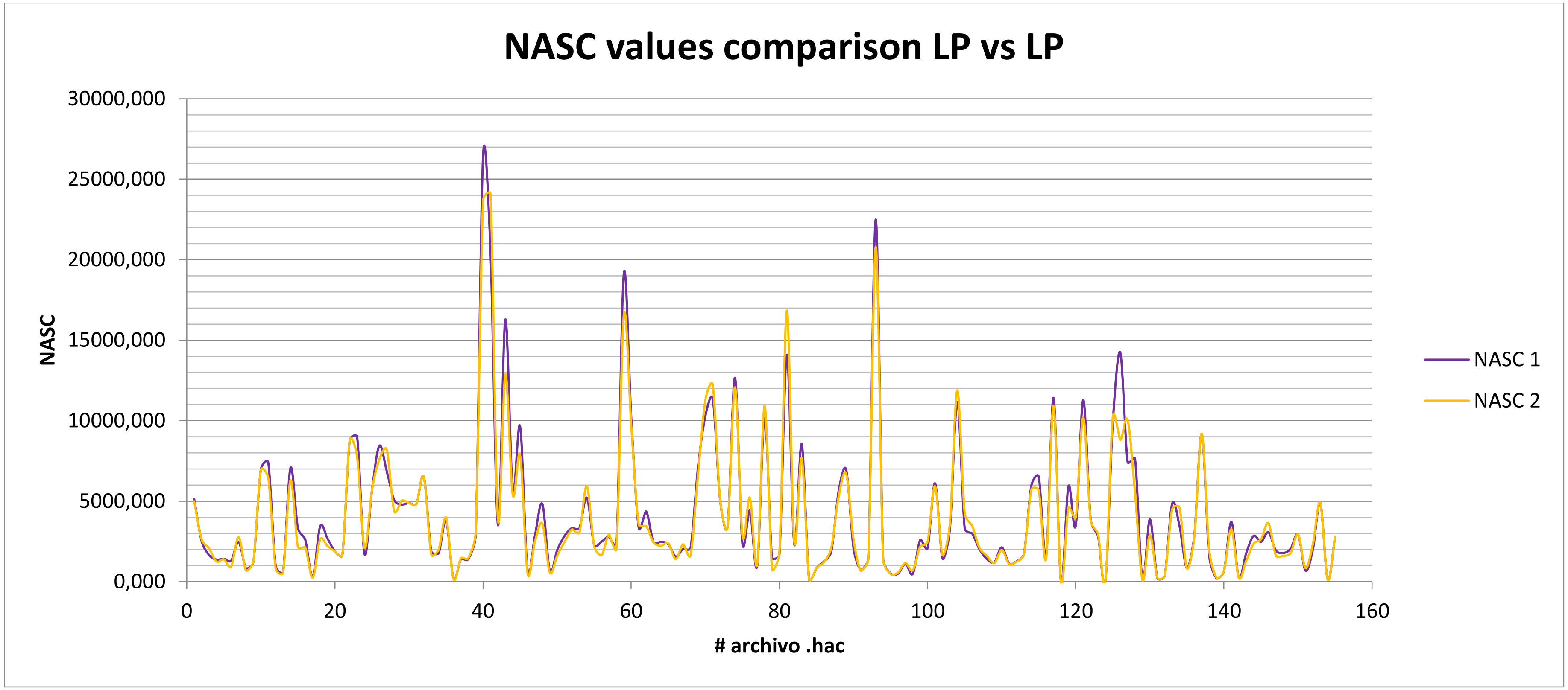


FIGURE 21. NASC VALUES COMPARISON LP VS LP SCRIPT.

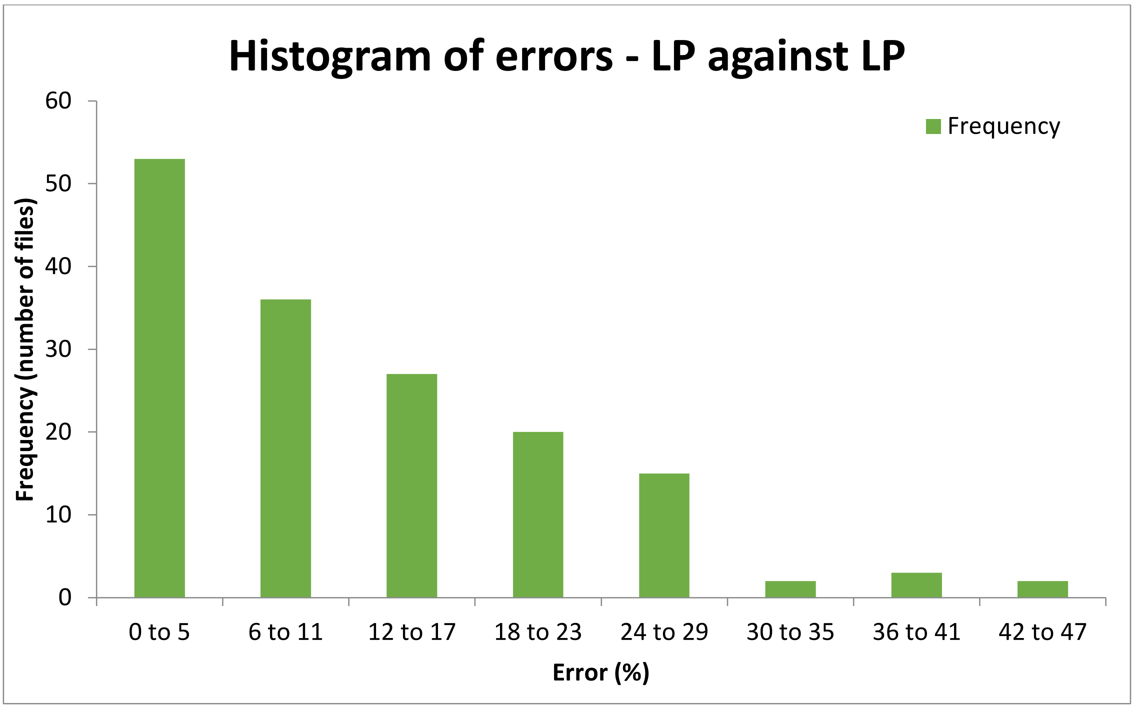


FIGURE 22. HISTOGRAM OF ERROR OBTAINED FROM LP SCRIPT RUNS

4.5. Sources of uncertainty

According to [63], there are six common sources of uncertainty in measurement results:

- Equipment: technical tools used to perform tests and calibrations.
- Object: unit under test.
- Operator: person in charge of performing tests.
- Method: system or processes used for tests and calibrations.
- Calibration: percentage of uncertainty reported on the calibration report.
- Environment: different variables that could have an influence in the tests such as pressure, vibration, temperature, etc.

The sources reported above can be measured and determinate how much these affect the uncertainty of our script. However, after our experience with both tools (Echoview and LP script) it seemed easy to identify which could be the highest contributor in uncertainty value.

The operator, in this case, the technician or acoustician in charge of the echogram analysis will determinate which are the targets of interest. Having this in mind, the way the user selects the target or how many pixels (dB) are selected will change the NASC value. This last fact will be affected by the acoustician's level of experience.

As the last part of LP validations we performed tests to quantify the uncertainty obtained from the operator. The tests consisted of running Echoview and LP script twice with 3 files (same from 4.1 and 4.2). These results are registered in tables #11 and #12 for Echoview and LP respectively.

FILE NAME	SCHOOLS	# POINTS	W/OUT COLUMN	PIXELS DIF	NASC 1 (m^2/NM^2)	NASC 2 (m^2/NM^2)	ERROR %	MEAN ERR (%)
D20111121-T000237	1	355	280	75	4223.27	5137.03	21.64	16.82
	2	395	280	115	5059.25	6226.89	23.08	
	3	438	360	78	2117.27	2528.71	19.43	
	4	623	510	113	2018.04	2178.13	7.93	
	5	220	159	61	531.03	467.11	12.04	
D20111121-T235413	1	1232	1044	188	9067.84	10165.48	12.10	14.23
	2	910	774	136	11595.06	13491.19	16.35	
D20111121-T002338	1	435	360	75	3394.59	4118.41	21.32	22.90
	2	395	316	79	973.96	1075.3	10.40	
	3	370	304	66	4067.36	4951.2	21.73	
	4	268	207	61	1135.6	1449.51	27.64	
	5	400	316	84	7373.32	9152.8	24.13	
	6	1521	1380	141	8998.24	9681.85	7.60	
	7	896	784	112	5442.63	6193.02	13.79	
	8	219	136	83	4269.51	1852.47	56.61	
						TOTAL MEAN		17.98

TABLE 11. NASC VALUES FOR ECHOVIEW AND ERRORS.

FILE NAME	SCHOOLS	# POINTS	W/OUT COLUMN	PIXELS DIF	NASC 1 (m^2/NM^2)	NASC 2 (m^2/NM^2)	ERROR %	MEAN ERR (%)
D20111121-T000237	1	104	63	41	5500.1	6459.85	17.45	19.2
	2	97	73	24	6192.41	7492.04	20.99	
	3	111	85	26	3797.37	3845.32	1.26	
	4	140	107	33	2851.57	3203.83	12.35	
	5	66	38	28	800.244	448.61	43.94	
D20111121-T235413	1	273	183	90	12456.2	10145.6	18.55	29
	2	176	127	49	13806.8	8361.42	39.44	
D20111121-T002338	1	131	98	33	3508.42	4163.55	18.67	21.42
	2	80	61	19	1417.64	1135.57	19.90	
	3	120	60	60	4918.25	6124.43	24.52	
	4	72	46	26	1475.53	805.206	45.43	
	5	103	76	27	8450.64	5767.28	31.75	
	6	366	228	138	13137.1	10836.6	17.51	
	7	187	113	74	8449.12	7695.23	8.92	
	8	68	28	40	3980.86	4166.54	4.66	
						TOTAL MEAN		23.21

TABLE 12. NASC VALUES FOR LP SCRIPT AND ERRORS.

NASC 1 value comes from selecting a target with the original number of pixels. NASC 2 value resulted from selecting same target excluding 1 of its columns. This difference was made to show how NASC values vary depending on how many pixels the user selected.

Final results show uncertainties of 17.98 % for Echoview and 23.21 % for LP script.

CONCLUSIONS Y RECOMMENDATIONS

Conclusions

1. We reviewed existing solution alternatives and determinated “R Studio” as the preffered developing platform.
2. We selected the most suitable functions from R Studio library described in Chapter 3. Additional information can be found in Appendix 1 and 4.
3. We made adjustments to the functions according to the user’s needs which can be found in Appendix 5.
4. We coded a routine to obtain NASC values structured in three parts: working directory/loading functions, echogram processing and data input for species biomass and abundance estimation. We named the script “LandPons” (LP). Complete LP code can be found in Appendix 1.
5. We validated LP script based on accuracy and precision. We obtained a range between 0 - 10 % (7.22 % mean) of accuracy for LP script itself. Also, results showed a range between 5 - 14 % of error from LP script against Echoview. LP precision results showed 89 out of 155 files presented and error range between 0 - 11 %.
6. LP script could be used from now on as an analysis tool adjusting parameters needed according the acoustic survey project.

Recommendations

1. We recommend the user has a basis in fisheries acoustics before running LP script.
2. We advise the user to organize folders with the necessary functions and files to be processed with LP script before its execution.
3. We encourage users to make adjustments according to their visualization and analysis requirements.
4. LP script can be improved in several techniques. Among them, we find highly recommendable to code target selection by region.
5. We encourage users to test LP script accuracy and precision against their common use software for echogram data analysis.

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APPENDIXES

LP SCRIPT

```
> setwd("C:/Users/user/Documents/LANDPONS/R_LANDPONS")
> library (echogram)
> source('~/LANDPONS/SIMULACIÓN/Funciones/ecogramaLP.R', echo=TRUE)
> source('~/LANDPONS/SIMULACIÓN/Funciones/puntosecoLP.R', echo=TRUE)
> source('~/LANDPONS/SIMULACIÓN/Funciones/ruidoLP.R', echo=TRUE)
> source('~/LANDPONS/SIMULACIÓN/Funciones/graficarecoLP.R', echo=TRUE)
> source('~/LANDPONS/SIMULACIÓN/Funciones/nascLP.R', echo=TRUE)
> source('~/LANDPONS/SIMULACIÓN/Funciones/coordnascLP.R', echo=TRUE)

> hacs <- list.files(pattern=glob2rx("*.hac"))
> nf <- length(hacs)
> prof.PPP <- -120 #PROFUNDIDAD PPP
> options(locatorBell = FALSE)
> e <- ecogramaLP(hacs[1])
> alfa <- e$alpha
> rm(e)
>                                  f                                  <-
matrix(nrow=nf,ncol=3,dimnames=list(hacs,c("longitude","latitude","NAS
C")))
> for (k in 1:nf) {
>  data <- hacs[k]
>  z <- ecogramaLP(hacs[k], channel=1)
>  z <- trim.echogram(z, depth.max =-prof.PPP, ping.ini = 0)
>  z <- mask.echogram(z, surf.off=3, bott.off=0.5, mask=TRUE)
>   v   <-   ruidoLP(z,   ping=50,   dB1m=-100,   alpha=alfa,   out=TRUE,
plot=FALSE)
>  z <- add.echogram(z, v, operator = "minus", domain="linear")
>  assign(paste("eco", k, sep="."), z)
>  graficarecoLP(z)
>  u <- puntosecoLP(z)
>  u <- u[!duplicated(u),]
>  u <- nascLP(u)
>  u <- u[order(u$pingTime), ]
>  id <- c(1:nrow(u))
>  u <- cbind(id,u)
>  assign(paste("pts", k, sep="."), u)
>  write.csv(u, file=paste("pts", hacs[k], "csv", sep="."))
>  r <- coordnascLP(z,u)
>  f[k,]<-r
>   }
```

```
>          j          <-           matrix(nrow=nf,           ncol=5,
dimnames=list(c(1:nf),c("f.macarela","f.botella","f.picudillo","f.pinc
hagua","f.otros")))
> write.csv(j, file=paste("Frecuencias", "csv", sep="."))
> j <- read.csv("Frecuencias.csv", header=TRUE, sep=",", dec=".")
> i <-as.vector(f[,"NASC"])
> nc <- ncol(j)
> j <- j[,2:nc]*i*0.01

> Transectas<-colSums(j, na.rm=TRUE)
> Promedio <- Transectas/nf

> tf <- cbind(f,j)
> View(tf) #ver resultados, copiar y pegar tabla de Excel

> write.csv(tf, file=paste("FinalTransect", "csv", sep="."))

> rm(x,y,z,v,u,id,k,nf,alfa,i,prof.PPP,hacs,data,ma,r,j,f,nc)
> rm(list=ls(pattern=glob2rx("pts.*")))
> rm(list=ls(pattern=glob2rx("eco.*")))
----------------------------------------------------------------------
```

LP SCRIPT USED FOR VALIDATIONS

```
> setwd("~/INTEGRADORA/VALIDACIONES/REP")

> library (echogram)

> source('~/funciones/ecogramaLP.R', echo=TRUE)

> source('~/funciones/puntosecoLP.R', echo=TRUE)

> source('~/funciones/ruidoLP.R', echo=TRUE)

> source('~/funciones/graficarecoLP.R', echo=TRUE)

> source('~/funciones/nascLP.R', echo=TRUE)

> source('~/funciones/coordnascLP.R', echo=TRUE)

> data <- "D20111121-T002314.hac"

> eco1 <- ecogramaLP(data, channel=1)

> prof.PPP <- -120

> options(locatorBell = FALSE)

> alfa <- eco1$alpha

> eco1.corte <- trim.echogram(eco1, depth.max =-prof.PPP, ping.ini =
3) #ping.ini depende de datos aberrantes de profundidad.

> masc1.eco <- mask.echogram(eco1.corte, surf.off=3, bott.off=0.5,
mask=TRUE)

> ruido1<- ruidoLP(masc1.eco, ping=50, dB1m=-100, alpha=alfa,
out=TRUE)

> eco1.corte.masc <- add.echogram(masc1.eco, ruido1, operator =
"minus", domain="linear")

> pts38 <- puntosecoLP(eco1.corte.masc)

> pts38 <- pts38[!duplicated(pts38),]

> pts38<-nascLP(pts38)

> pts38 <- pts38[order(pts38$pingTime), ]

> id <- c(1:nrow(pts38))

> pts38 <- cbind(id,pts38)

> r <- coordnascLP(eco1.corte.masc,pts38)

----------------------------------------------------------------------
```

ECHOVIEW – LP SCRIPT TABLE OF COMPARISON

	longitude	latitude	#pointsR	NASC R (m^2/NM^2)	#pointsE	NASC E (m^2/NM^2)	ERROR	ERROR (%)	ABS ERR (%)
1	-77.6197	-11.3960	35	2275.917	80	2311.53	0.015	1.541	1.541
2	-77.6135	-11.3999	11	156.4131	36	133.53	-0.171	-17.137	17.137
3	-77.6075	-11.4041	6	307.1008	18	484.69	0.366	36.640	36.640
4	-77.6017	-11.4085	40	402.672	150	379.76	-0.060	-6.033	6.033
5	-77.5958	-11.4129	50	512.0329	324	630.04	0.187	18.730	18.730
6	-77.5899	-11.4172	28	616.3976	78	633.77	0.027	2.741	2.741
7	-77.5838	-11.4214	34	1081.468	78	901.4	-0.200	-19.976	19.976
8	-77.5778	-11.4255	73	717.1448	188	665.67	-0.077	-7.733	7.733
9	-77.5718	-11.4297	27	572.2443	60	501.98	-0.140	-13.997	13.997
10	-77.5659	-11.4340	31	2066.547	82	2086.93	0.010	0.977	0.977
11	-77.5598	-11.4381	17	794.1228	37	805.44	0.014	1.405	1.405
12	-77.5538	-11.4422	21	627.5708	54	690.03	0.091	9.052	9.052
13	-77.5477	-11.4463	14	156.4918	42	190.66	0.179	17.921	17.921
14	-77.5417	-11.4504	6	387.7826	11	442.6	0.124	12.385	12.385
15	-77.5358	-11.4547	16	86.28281	85	114.6	0.247	24.710	24.710
16	-77.5383	-11.4591	51	104.4825	164	133.95	0.220	21.999	21.999
17	-77.5450	-11.4630	9	67.49153	15	77.07	0.124	12.428	12.428
18	-77.5515	-11.4674	19	251.7536	80	237.13	-0.062	-6.167	6.167
19	-77.5580	-11.4718	24	349.5649	44	307.13	-0.138	-13.817	13.817
20	-77.5649	-11.4758	7	190.2911	15	203.92	0.067	6.683	6.683
21	-77.5717	-11.4798	8	1556.429	10	2062.09	0.245	24.522	24.522
22	-77.5785	-11.4839	10	137.9385	20	103.94	-0.327	-32.710	32.710
23	-77.5853	-11.4881	47	499.6295	144	453.91	-0.101	-10.072	10.072
24	-77.5919	-11.4923	17	152.0383	40	150.83	-0.008	-0.801	0.801
25	-77.5985	-11.4965	48	190.1512	196	176.98	-0.074	-7.442	7.442
26	-77.6052	-11.5006	31	716.17	102	639.87	0.119	11.924	11.924
27	-77.6120	-11.5047	16	45	40	44.67	0.007	0.739	0.739
28	-77.6189	-11.5086	24	249.2254	84	278.27	-0.104	-10.438	10.438
29	-77.6258	-11.5124	52	675.4225	195	544.94	0.239	23.944	23.944

30	-77.6326	-11.5164	36	157.941	176	211.52	-0.253	-25.330	25.330
31	-77.6391	-11.5208	7	19.36511	15	24.51	-0.210	-20.991	20.991
32	-77.6456	-11.5252	8	188.1332	15	155.62	0.209	20.893	20.893
33	-77.6526	-11.5294	6	3.847618	6	3.76	0.023	2.330	2.330
34	-77.6615	-11.5347	9	2060.745	10	2015.33	0.023	2.253	2.253
35	-77.6716	-11.5409	11	438.7236	21	430.25	0.020	1.969	1.969
36	-77.6816	-11.5471	25	278.5832	95	282.15	-0.013	-1.264	1.264
37	-77.6916	-11.5533	117	1128.238	504	930.3	0.213	21.277	21.277
38	-77.7017	-11.5594	191	1204.396	804	952.55	0.264	26.439	26.439
39	-77.7117	-11.5656	346	2057.603	1340	1974.04	0.042	4.233	4.233
40	-77.7217	-11.5717	356	15871.18	2208	16872.28	-0.059	-5.933	5.933
41	-77.7316	-11.5778	238	3419.67	900	2971.35	0.151	15.088	15.088
42	-77.7410	-11.5835	303	13536.29	1164	14569.01	-0.071	-7.088	7.088
43	-77.7471	-11.5856	158	1975.955	520	1609.78	0.227	22.747	22.747
44	-77.7511	-11.5877	305	7909.371	1200	8361.13	-0.054	-5.403	5.403
45	-77.7547	-11.5907	32	322.2058	112	357.06	-0.098	-9.761	9.761
46	-77.7577	-11.5935	38	3047.183	132	2456	0.241	24.071	24.071
47	-77.7605	-11.5960	120	1530.717	423	1543.33	-0.008	-0.817	0.817
48	-77.7625	-11.5973	23	953.2093	39	772.19	0.234	23.442	23.442
49	-77.7650	-11.5986	45	2782.447	109	3063.39	-0.092	-9.171	9.171
50	-77.7672	-11.6005	14	2610.686	27	1964.65	0.329	32.883	32.883
51	-77.7689	-11.6016	11	2389.372	19	2124.62	0.125	12.461	12.461
52	-77.7705	-11.6024	156	4086.36	522	3189.83	0.281	28.106	28.106
53	-77.7724	-11.6032	354	2868.555	1403	2337.19	0.227	22.735	22.735
54	-77.7801	-11.6074	25	2408.359	63	2066.32	0.166	16.553	16.553
55	-77.7904	-11.6135	4	1036.425	5	1314.25	-0.211	-21.139	21.139
56	-77.8003	-11.6199	13	1810.207	30	1657.17	0.092	9.235	9.235
57	-77.8096	-11.6260	25	4044.696	61	3631.18	0.114	11.388	11.388
58	-77.8167	-11.6305	451	13204.63	2280	16631.22	-0.206	-20.603	20.603
59	-77.8209	-11.6363	23	1240.718	45	1008.33	0.230	23.047	23.047
60	-77.8234	-11.6433	32	6314.391	93	6139.57	0.028	2.847	2.847
61	-77.8254	-11.6503	36	5567.054	96	4811.01	0.157	15.715	15.715
62	-77.8268	-11.6572	42	2943.079	91	2798.01	0.052	5.185	5.185

63	-77.8250	-11.6638	13	365.3111	33	342.88	0.065	6.542	6.542
64	-77.8205	-11.6694	24	2129.797	50	2015.24	0.057	5.685	5.685
65	-77.8186	-11.6756	39	7763.654	100	7392.53	0.050	5.020	5.020
66	-77.8238	-11.6810	20	5872.002	63	4958.9	0.184	18.413	18.413
67	-77.8298	-11.6859	30	2798.178	82	2711.31	0.032	3.204	3.204
68	-77.8357	-11.6909	18	3517.821	34	3481.46	0.010	1.044	1.044
69	-77.8399	-11.6971	36	15857.19	95	15168.88	0.045	4.538	4.538
70	-77.8427	-11.7042	28	19570.88	67	19980.85	-0.021	-2.052	2.052
71	-77.8453	-11.7113	52	5718.148	126	5954.24	-0.040	-3.965	3.965
72	-77.8474	-11.7184	35	3149.378	79	3381.33	-0.069	-6.860	6.860
73	-77.8492	-11.7257	34	5545.234	84	6287.28	-0.118	-11.802	11.802
74	-77.8513	-11.7328	19	936.2416	30	814.29	0.150	14.976	14.976
75	-77.8534	-11.7400	25	3006.155	64	3834.27	-0.216	-21.598	21.598
76	-77.8555	-11.7471	19	798.9472	31	858.19	-0.069	-6.903	6.903
77	-77.8576	-11.7543	8	616.3366	12	703.52	-0.124	-12.392	12.392
78	-77.8596	-11.7616	25	3335.819	45	3316.18	0.006	0.592	0.592
79	-77.8618	-11.7686	18	11190.79	28	11788.24	-0.051	-5.068	5.068
80	-77.8643	-11.7756	27	1163.59	43	1274.39	-0.087	-8.694	8.694
81	-77.8667	-11.7828	11	611.4949	20	625.73	-0.023	-2.275	2.275
82	-77.8660	-11.7868	37	39289.96	64	37235.64	0.055	5.517	5.517
83	-77.8598	-11.7831	22	3696.643	44	3706.2	-0.003	-0.258	0.258
84	-77.8533	-11.7793	24	11092.93	48	9976.76	0.112	11.188	11.188
85	-77.8465	-11.7758	7	839.9984	13	954.99	-0.120	-12.041	12.041
86	-77.8399	-11.7723	19	1273.285	40	1344.91	-0.053	-5.326	5.326
87	-77.8335	-11.7684	15	1017.967	31	999.8	0.018	1.817	1.817
88	-77.8271	-11.7646	32	4664.75	66	4232.32	0.102	10.217	10.217
89	-77.8207	-11.7608	17	1959.225	41	1782.74	0.099	9.900	9.900
90	-77.8143	-11.7571	21	21030.12	45	18965.44	0.109	10.887	10.887
91	-77.8078	-11.7533	27	2788.904	58	2473.55	0.127	12.749	12.749
92	-77.8014	-11.7495	33	1589.956	75	1672.07	-0.049	-4.911	4.911
93	-77.7951	-11.7455	9	2901.123	18	2811.1	0.032	3.202	3.202
94	-77.7889	-11.7412	22	24515.13	53	22563.16	0.087	8.651	8.651
95	-77.7825	-11.7372	26	796.7126	57	905.37	-0.120	-12.001	12.001

96	-77.7760	-11.7333	33	7882.647	63	7957.04	-0.009	-0.935	0.935
97	-77.7696	-11.7292	23	4135.001	53	4017.28	0.029	2.930	2.930
98	-77.7632	-11.7252	18	11602.59	42	11775.66	-0.015	-1.470	1.470
99	-77.7566	-11.7214	21	8088.92	52	8986.15	-0.100	-9.985	9.985
100	-77.7500	-11.7176	17	1935.703	29	2150.47	-0.100	-9.987	9.987
101	-77.7433	-11.7136	38	2700.778	80	2660.25	-0.015	-1.523	1.523
102	-77.7366	-11.7097	15	958.0419	43	1177.78	0.187	18.657	18.657
103	-77.7300	-11.7058	16	491.2926	63	464.32	-0.058	-5.809	5.809
104	-77.7234	-11.7020	20	973.2015	59	1053.82	0.077	7.650	7.650
105	-77.7167	-11.6983	6	265.2732	16	269.45	0.016	1.550	1.550
106	-77.7099	-11.6946	291	3148.935	1100	3037.03	-0.037	-3.685	3.685
107	-77.7033	-11.6906	29	2031.408	68	2236.02	0.092	9.151	9.151
108	-77.6969	-11.6864	8	3234.355	21	3495.02	0.075	7.458	7.458
109	-77.6904	-11.6823	25	1388.944	74	1526.44	0.090	9.008	9.008
110	-77.6837	-11.6786	16	468.5443	84	507.37	0.077	7.652	7.652
111	-77.6769	-11.6750	24	4298.279	64	4108.31	-0.046	-4.624	4.624
112	-77.6703	-11.6713	17	1638.843	42	1758.24	0.068	6.791	6.791
113	-77.6638	-11.6671	35	1482.536	103	1597.03	0.072	7.169	7.169
114	-77.6574	-11.6628	22	1285.698	58	1266.9	-0.015	-1.484	1.484
115	-77.6511	-11.6586	202	3142.035	522	2961.28	-0.061	-6.104	6.104
116	-77.6444	-11.6549	31	4067.819	65	3549.28	-0.146	-14.610	14.610
117	-77.6376	-11.6513	16	1928.66	36	1707.77	-0.129	-12.934	12.934
118	-77.6310	-11.6475	78	2378.681	227	2267.14	-0.049	-4.920	4.920
119	-77.6243	-11.6437	46	3888.347	177	3925.06	0.009	0.935	0.935
120	-77.6176	-11.6400	20	11987.22	46	10854.85	-0.104	-10.432	10.432
121	-77.6111	-11.6360	47	2693.568	108	2645.68	-0.018	-1.810	1.810
122	-77.6046	-11.6319	92	2342.587	291	1985.98	-0.180	-17.956	17.956
123	-77.5981	-11.6280	107	2316.403	287	1985.73	-0.167	-16.652	16.652
124	-77.5915	-11.6242	20	724.7022	44	623.85	-0.162	-16.166	16.166
125	-77.5849	-11.6204	12	166.0279	20	127.9	-0.298	-29.811	29.811
126	-77.5782	-11.6166	44	1700.83	104	1725.35	0.014	1.421	1.421
127	-77.5715	-11.6128	37	479.2006	92	404.01	-0.186	-18.611	18.611
128	-77.5635	-11.6079	54	7868.869	127	8226.43	0.043	4.346	4.346

129	-77.5542	-11.6016	43	5623.199	110	6442.45	0.127	12.716	12.716
130	-77.5443	-11.5961	281	10389.22	1281	10384.57	0.000	-0.045	0.045
131	-77.5345	-11.5904	16	637.8351	34	679.8	0.062	6.173	6.173
132	-77.5250	-11.5844	23	7871.453	55	7500.07	-0.050	-4.952	4.952
133	-77.5154	-11.5784	41	26168.3	92	24041.53	-0.088	-8.846	8.846
134	-77.5057	-11.5726	31	1819.885	66	1645.12	-0.106	-10.623	10.623
135	-77.4958	-11.5669	14	9640.556	25	10470.75	0.079	7.929	7.929
136	-77.4860	-11.5612	26	8412.108	44	7632.93	-0.102	-10.208	10.208
137	-77.4762	-11.5554	32	20450.33	76	23299.58	0.122	12.229	12.229
138	-77.4665	-11.5492	25	9654.926	56	9191.66	-0.050	-5.040	5.040
139	-77.4567	-11.5433	30	8891.652	71	10518.28	0.155	15.465	15.465
140	-77.4467	-11.5376	40	14320.69	98	13138.78	-0.090	-8.996	8.996
141	-77.4367	-11.5322	26	5431.912	51	4431.17	-0.226	-22.584	22.584
142	-77.4268	-11.5346	22	1972.889	48	1785.34	-0.105	-10.505	10.505
143	-77.4190	-11.5400	38	1158.573	82	1347.38	0.140	14.013	14.013
144	-77.4126	-11.5442	42	2027.851	94	1851.4	-0.095	-9.531	9.531
145	-77.4061	-11.5484	10	1533.718	18	1769.22	0.133	13.311	13.311
146	-77.3998	-11.5530	24	4410.064	64	3664.16	-0.204	-20.357	20.357
147	-77.3936	-11.5577	29	1816.191	64	1834.45	0.010	0.995	0.995
148	-77.3873	-11.5623	35	1768.454	83	1869.92	0.054	5.426	5.426
149	-77.3810	-11.5667	36	5453.156	89	4349.89	-0.254	-25.363	25.363
150	-77.3746	-11.5711	29	1100.769	62	1059.47	-0.039	-3.898	3.898
151	-77.3681	-11.5755	18	4083.415	36	4600.76	0.112	11.245	11.245
152	-77.3617	-11.5799	32	1599.837	80	1521.37	-0.052	-5.158	5.158
153	-77.3557	-11.5847	302	3131.968	1092	2504.23	-0.251	-25.067	25.067
154	-77.3495	-11.5894	25	534.6354	48	467.72	-0.143	-14.307	14.307
155	-77.3431	-11.5938	16	692.1888	45	572.99	-0.208	-20.803	20.803
156	-77.3377	-11.5972	14	1162.527	25	1278.34	0.091	9.060	9.060

LP SCRIPT NASC VALUES TABLE OF COMPARISON

N	Archivo	#pts	NASC 1 (m^2/NM^2)	NASC 2 (m^2/NM^2)	ERROR	ERROR %	ABS ERR (%)
1	D20111120-T171403.hac	39	5143.899	4997.623	0.028	2.844	2.844
2	D20111120-T171652.hac	15	2539.885	2648.671	-0.043	-4.283	4.283
3	D20111120-T171941.hac	9	1664.612	2080.763	-0.250	-25.000	25.000
4	D20111120-T172230.hac	29	1375.884	1260.649	0.084	8.375	8.375
5	D20111120-T172519.hac	59	1421.021	1389.489	0.022	2.219	2.219
6	D20111120-T172808.hac	37	1316.917	950.263	0.278	27.842	27.842
7	D20111120-T173057.hac	73	2470.674	2773.307	-0.122	-12.249	12.249
8	D20111120-T173346.hac	44	824.138	693.275	0.159	15.879	15.879
9	D20111120-T173635.hac	39	1249.763	1310.025	-0.048	-4.822	4.822
10	D20111120-T173924.hac	60	6981.653	6950.247	0.004	0.450	0.450
11	D20111120-T174213.hac	10	7402.439	6444.354	0.129	12.943	12.943
12	D20111120-T174502.hac	12	1002.246	827.127	0.175	17.473	17.473
13	D20111120-T174752.hac	29	616.233	561.335	0.089	8.909	8.909
14	D20111120-T175041.hac	5	7071.909	6292.449	0.110	11.022	11.022
15	D20111120-T175330.hac	30	3354.101	2173.063	0.352	35.212	35.212
16	D20111120-T175620.hac	20	2599.464	2122.126	0.184	18.363	18.363
17	D20111120-T175910.hac	10	311.482	251.161	0.194	19.366	19.366
18	D20111120-T180159.hac	20	3427.142	2635.292	0.231	23.105	23.105
19	D20111120-T180448.hac	13	2681.252	2211.844	0.175	17.507	17.507
20	D20111120-T180737.hac	4	1886.911	1886.911	0.000	0.000	0.000
21	D20111120-T181026.hac	4	1646.173	1646.173	0.000	0.000	0.000
22	D20111120-T181315.hac	10	8790.461	8790.461	0.000	0.000	0.000
23	D20111120-T181604.hac	30	8984.709	7735.052	0.139	13.909	13.909
24	D20111120-T181853.hac	7	1708.405	2106.134	-0.233	-23.281	23.281
25	D20111120-T182142.hac	8	5689.786	5689.786	0.000	0.000	0.000
26	D20111120-T182431.hac	13	8444.345	7603.834	0.100	9.954	9.954
27	D20111120-T182720.hac	10	6855.138	8188.584	-0.195	-19.452	19.452
28	D20111120-T183009.hac	12	5070.408	4384.430	0.135	13.529	13.529
29	D20111120-T183258.hac	11	4794.033	5033.588	-0.050	-4.997	4.997
30	D20111120-T183547.hac	7	4897.387	4897.387	0.000	0.000	0.000
31	D20111120-T183836.hac	5	4840.807	4840.807	0.000	0.000	0.000
32	D20111120-T184126.hac	4	6503.946	6503.946	0.000	0.000	0.000
33	D20111120-T184418.hac	9	1904.135	1696.387	0.109	10.910	10.910
34	D20111120-T184724.hac	19	1767.212	1997.846	-0.131	-13.051	13.051
35	D20111120-T185137.hac	132	3773.369	3970.217	-0.052	-5.217	5.217
36	D20111120-T185550.hac	76	220.332	168.398	0.236	23.571	23.571
37	D20111120-T190004.hac	207	1383.944	1449.842	-0.048	-4.762	4.762
38	D20111120-T190417.hac	192	1408.224	1470.040	-0.044	-4.390	4.390
39	D20111120-T190831.hac	377	2925.488	3088.474	-0.056	-5.571	5.571
40	D20111120-T191244.hac	397	26528.990	23728.210	0.106	10.557	10.557

41	D20111120-T191434.hac	386	20456.300	24089.540	-0.178	-17.761	17.761
42	D20111120-T191658.hac	183	3529.496	3889.577	-0.102	-10.202	10.202
43	D20111120-T192111.hac	209	16291.730	12884.360	0.209	20.915	20.915
44	D20111120-T192525.hac	45	5765.127	5397.830	0.064	6.371	6.371
45	D20111120-T192938.hac	441	9638.110	7834.639	0.187	18.712	18.712
46	D20111120-T193352.hac	14	718.568	538.755	0.250	25.024	25.024
47	D20111120-T193805.hac	17	2890.618	2513.110	0.131	13.060	13.060
48	D20111120-T194219.hac	118	4824.823	3601.584	0.254	25.353	25.353
49	D20111120-T194632.hac	8	694.492	576.654	0.170	16.968	16.968
50	D20111120-T195046.hac	66	1965.580	1616.967	0.177	17.736	17.736
51	D20111120-T195459.hac	113	2850.460	2485.281	0.128	12.811	12.811
52	D20111120-T195913.hac	26	3335.417	3251.954	0.025	2.502	2.502
53	D20111120-T200326.hac	15	3325.746	3069.000	0.077	7.720	7.720
54	D20111120-T200740.hac	35	5215.302	5943.089	-0.140	-13.955	13.955
55	D20111120-T201153.hac	20	2263.841	2186.322	0.034	3.424	3.424
56	D20111120-T201607.hac	244	2496.284	1651.951	0.338	33.824	33.824
57	D20111120-T202020.hac	105	2794.153	2953.427	-0.057	-5.700	5.700
58	D20111120-T202434.hac	394	2277.592	2054.600	0.098	9.791	9.791
59	D20111120-T202752.hac	424	19169.090	16590.210	0.135	13.453	13.453
60	D20111120-T203041.hac	354	10167.500	9679.270	0.048	4.802	4.802
61	D20111120-T203330.hac	18	3360.897	3562.490	-0.060	-5.998	5.998
62	D20111120-T203619.hac	362	4369.449	3462.205	0.208	20.763	20.763
63	D20111120-T203908.hac	225	2467.014	2455.352	0.005	0.473	0.473
64	D20111120-T204157.hac	20	2479.113	2231.382	0.100	9.993	9.993
65	D20111120-T204446.hac	18	2328.227	2376.647	-0.021	-2.080	2.080
66	D20111120-T204735.hac	48	1561.511	1402.256	0.102	10.199	10.199
67	D20111120-T205024.hac	137	2039.890	2324.620	-0.140	-13.958	13.958
68	D20111120-T205313.hac	62	2097.761	1636.634	0.220	21.982	21.982
69	D20111120-T205602.hac	119	7071.406	6594.674	0.067	6.742	6.742
70	D20111120-T205851.hac	21	10302.260	11293.710	-0.096	-9.624	9.624
71	D20111120-T210140.hac	67	11354.120	12200.880	-0.075	-7.458	7.458
72	D20111120-T210429.hac	71	5009.997	5050.316	-0.008	-0.805	0.805
73	D20111120-T210718.hac	87	3439.130	3403.424	0.010	1.038	1.038
74	D20111120-T211007.hac	63	12661.510	12080.140	0.046	4.592	4.592
75	D20111120-T211256.hac	44	2370.399	2876.089	-0.213	-21.334	21.334
76	D20111120-T211545.hac	24	4421.556	5221.628	-0.181	-18.095	18.095
77	D20111120-T211834.hac	11	990.817	1091.992	-0.102	-10.211	10.211
78	D20111120-T212701.hac	7	10177.600	10915.620	-0.073	-7.251	7.251
79	D20111120-T212950.hac	6	1487.571	783.7487	0.473	47.314	47.314
80	D20111120-T213239.hac	10	1703.794	1856.67	-0.090	-8.973	8.973
81	D20111120-T213528.hac	9	14104.81	16847.91	-0.194	-19.448	19.448
82	D20111120-T213817.hac	6	2337.618	2524.636	-0.080	-8.000	8.000
83	D20111120-T214106.hac	9	8548.904	7676.991	0.102	10.199	10.199
84	D20111120-T214355.hac	4	153.641	153.641	0.000	0.000	0.000

85	D20111120-T214644.hac	9	862.039	869.7498	-0.009	-0.894	0.894
86	D20111120-T214933.hac	9	1260.27	1221.443	0.031	3.081	3.081
87	D20111120-T215222.hac	12	1885.582	2121.088	-0.125	-12.490	12.490
88	D20111120-T215511.hac	18	5663.763	5305.036	0.063	6.334	6.334
89	D20111120-T215800.hac	29	6964.157	6711.95	0.036	3.622	3.622
90	D20111120-T220049.hac	14	2073.236	2640.677	-0.274	-27.370	27.370
91	D20111120-T220338.hac	20	717.9571	676.6897	0.057	5.748	5.748
92	D20111120-T220627.hac	14	1476.248	1455.41	0.014	1.412	1.412
93	D20111120-T220916.hac	16	22502.28	20798.97	0.076	7.569	7.569
94	D20111120-T221205.hac	8	1423.355	1370.862	0.037	3.688	3.688
95	D20111120-T221454.hac	17	514.1092	484.698	0.057	5.721	5.721
96	D20111120-T221743.hac	21	498.5393	577.1478	-0.158	-15.768	15.768
97	D20111120-T222033.hac	17	1116.752	1168.352	-0.046	-4.621	4.621
98	D20111120-T222322.hac	9	490.0156	711.2078	-0.451	-45.140	45.140
99	D20111120-T222611.hac	7	2601.365	2185.061	0.160	16.003	16.003
100	D20111120-T222900.hac	27	2098.963	2504.068	-0.193	-19.300	19.300
101	D20111120-T223151.hac	23	6113.547	5929.209	0.030	3.015	3.015
102	D20111120-T223440.hac	22	1443.627	1664.336	-0.153	-15.289	15.289
103	D20111120-T223729.hac	14	3249.546	3609.517	-0.111	-11.078	11.078
104	D20111120-T224018.hac	37	11158.51	11886.07	-0.065	-6.520	6.520
105	D20111120-T224307.hac	23	3326.35	4272.378	-0.284	-28.441	28.441
106	D20111120-T224556.hac	4	3004.402	3490.475	-0.162	-16.179	16.179
107	D20111120-T224845.hac	17	2011.829	2103.496	-0.046	-4.556	4.556
108	D20111120-T225134.hac	8	1412.516	1611.738	-0.141	-14.104	14.104
109	D20111120-T225423.hac	5	1203.298	1158.111	0.038	3.755	3.755
110	D20111120-T225712.hac	16	2131.674	1965.218	0.078	7.809	7.809
111	D20111120-T230001.hac	9	1137.548	1109.715	0.024	2.447	2.447
112	D20111120-T230250.hac	9	1268.814	1245.3	0.019	1.853	1.853
113	D20111120-T230539.hac	13	1725.679	1690.979	0.020	2.011	2.011
114	D20111120-T230828.hac	15	5970.992	5718.281	0.042	4.232	4.232
115	D20111120-T231117.hac	14	6517.907	5655.532	0.132	13.231	13.231
116	D20111120-T231406.hac	7	1704.441	1440.102	0.155	15.509	15.509
117	D20111120-T231655.hac	15	11420.24	10916.84	0.044	4.408	4.408
118	D20111120-T231944.hac	2	2.603455	2.603455	0.000	0.000	0.000
119	D20111120-T232233.hac	7	5921.648	4613.09	0.221	22.098	22.098
120	D20111120-T232522.hac	10	3495.789	4009.564	-0.147	-14.697	14.697
121	D20111120-T232811.hac	16	11291.03	10198.96	0.097	9.672	9.672
122	D20111120-T233100.hac	7	3895.108	3840.034	0.014	1.414	1.414
123	D20111120-T233349.hac	8	2827.535	2976.439	-0.053	-5.266	5.266
124	D20111120-T233639.hac	3	74.4977	74.4977	0.000	0.000	0.000
125	D20111120-T233929.hac	19	9931.169	10271.5	-0.034	-3.427	3.427
126	D20111120-T234219.hac	26	14237.86	8820.342	0.381	38.050	38.050
127	D20111120-T234516.hac	16	7423.149	10034.52	-0.352	-35.179	35.179

128	D20111120-T234925.hac	23	7629.118	5474.208	0.282	28.246	28.246
129	D20111120-T235338.hac	6	149.0844	110.4683	0.259	25.902	25.902
130	D20111120-T235752.hac	11	3882.744	2905.246	0.252	25.175	25.175
131	D20111121-T000205.hac	11	233.6868	248.5443	-0.064	-6.358	6.358
132	D20111121-T000619.hac	3	378.3902	378.3902	0.000	0.000	0.000
133	D20111121-T001032.hac	26	4829.932	4488.504	0.071	7.069	7.069
134	D20111121-T001446.hac	5	3456.233	4604.776	-0.332	-33.231	33.231
135	D20111121-T001900.hac	7	834.7934	828.3935	0.008	0.767	0.767
136	D20111121-T002314.hac	13	2914.91	2792.07	0.042	4.214	4.214
137	D20111121-T002727.hac	12	9173.629	9188.951	-0.002	-0.167	0.167
138	D20111121-T003141.hac	13	1602.531	1988.45	-0.241	-24.082	24.082
139	D20111121-T003554.hac	11	209.7132	254.8101	-0.215	-21.504	21.504
140	D20111121-T004008.hac	8	676.9523	691.616	-0.022	-2.166	2.166
141	D20111121-T004421.hac	12	3714.181	3261.879	0.122	12.178	12.178
142	D20111121-T004832.hac	14	263.6527	242.7491	0.079	7.928	7.928
143	D20111121-T005121.hac	13	1773.633	1296.602	0.269	26.896	26.896
144	D20111121-T005410.hac	16	2847.902	2359.493	0.171	17.150	17.150
145	D20111121-T005659.hac	19	2475.699	2644.328	-0.068	-6.811	6.811
146	D20111121-T005948.hac	5	3070.296	3634.497	-0.184	-18.376	18.376
147	D20111121-T010237.hac	21	1948.338	1634.133	0.161	16.127	16.127
148	D20111121-T010526.hac	19	1782.442	1607.202	0.098	9.831	9.831
149	D20111121-T010815.hac	16	2050.804	1791.101	0.127	12.663	12.663
150	D20111121-T011104.hac	4	2933.838	2933.838	0.000	0.000	0.000
151	D20111121-T011353.hac	8	692.7862	855.7756	-0.235	-23.527	23.527
152	D20111121-T011642.hac	8	1994.204	2340.165	-0.173	-17.348	17.348
153	D20111121-T011931.hac	8	4888.585	4888.585	0.000	0.000	0.000
154	D20111121-T012220.hac	8	136.5393	140.7651	-0.031	-3.095	3.095
155	D20111121-T012509.hac	6	2790.913	2790.913	0.000	0.000	0.000

FUNCTIONS COORDNASCLP AND NASCLP CODES

```
> coordnascLP<- function(echogram, data.frame) {
+ echo <- echogram
+ data <- data.frame
+ lon <- mean(echo$pings$lon)
+ lat <- mean(echo$pings$lat)
+ nasc <- data$meanNASC[1]
+ ans <- cbind(lon,lat,nasc)
+ ans
+ }
>
```

```
> nascLP <- function(data.frame) {
+     pts <- data.frame
+     if (class(pts) != "data.frame")
+       stop("Necesita objeto de tipo 'data.frame'")
+     a <- 4*pi*1852^2
+     b <- (max(pts$Profundidad) - min(pts$Profundidad))
+     c <- 10^(pts$Sv*0.1)
+     NASC <- a*b*c
+     pts.NASC <- cbind(pts,NASC)
+     meanNASC <- mean(pts.NASC$NASC, na.rm=TRUE)
+     ans <- cbind(pts.NASC,meanNASC)
+     ans
+ }
>
```

INTERNAL ADJUSTMENTS TO OTHER FUNCTIONS

Function *puntosecoLP*

```
8 graficarecoLP(echo, scheme=c("blue", "green", "yellow", "orange", "red", "pink"), col.sep=0.05, Svthr=-70)
23 lo <- rep(echo$pings$lon, each = ny)
24 la <- rep(echo$pings$lat, each = ny)
25 ans <- data.frame(X = vX, Ym = vYm, Yi = vYi, pingTime = pt, Lon = lo, Lat = la, Profundidad = dp, Sv = z)
38 ans <- data.frame(coords, pingTime = NA, Lon=NA, Lat=NA,
                     Profundidad = NA, Sv = NA)
48 ans[i, "Lon"] <- echoL[which.min(d), "Lon"]
49 ans[i, "Lat"] <- echoL[which.min(d), "Lat"]
```

Function *ruidoLP*

```
27 if ((alpha)>1) {
28   alpha <- alpha/1000
29 }
33 plot(x = DS$Sv, y = -DS$Depth, xlab = expression(paste(S[v],
34 "(dB)")), ylab = "Profundidad (m)", cex = 0.5, pch = 16,
35 type = "o", col = rgb(0, 0, 1, 0.3), main = paste("Ruido estimado;",
36 "Frecuencia=",frq, "(Alfa=", alpha, "dB/m; R(1 m)=",round(dB1m),
37 "dB )"), las = 1)
```

Function *graficarecoLP*

```
1 graficarecoLP <- function (echogram, xref = c("ping", "distance", "time"), scheme=c("blue", "green", "yellow", "orange", "red", "pink"),
2 Svthr = -70, Svmax = NULL, col.sep = 0.05, colbar = TRUE, main = NULL,
3 ...)
68 Svmax <- -34
```

Function *ecogramaLP*

```
43 frq <- readHAC::parseHAC(chanTup)$"Acoustic frequency"/1000
47 alpha <- readHAC::parseHAC(chanTup)$"Absorption coefficient"
59 dbot <- data.frame(bot, speed = NA, cumdist = NA, lon=NA, lat=NA)
67 for (m in 1:np) {
68      l <- bot$pingTime[m]
69      tdif <- abs(difftime(pos$time.cpu, l, units = "secs"))
70      idx <- which.min(tdif)
71      dbot[m, "lon"] <- pos$lon[idx]
72      }
73 for (n in 1:np) {
74      h <- bot$pingTime[n]
```

```
     tdif <- abs(difftime(pos$time.cpu, h, units = "secs"))
     idx <- which.min(tdif)
     dbot[n, "lat"] <- pos$lat[idx]
     }
ans <- list(depth = depth, Sv = Sv, pings = dbot, alpha=alpha)
```