First International Scientific Workshop for the Argentine Shortfin Squid
29th Nov – 1st Dec 2022, Las Cruces, Chile

Hosted by CAPES-UC, Center of Applied Ecology and Sustainability, Pontificia Universidad Católica de Chile

Report of work of sessions and way forward

Rubén H. Roa-Ureta and Rodrigo Wiff,
Chairman and co-chair of the workshop

1. Executive summary

A workshop on the stock assessment and management of the *Illex argentinus* stock in the South West Atlantic was held between 29th November and 1st December 2022 in Las Cruces, Valparaíso, Chile. Hosted by the Center for Applied Ecology & Sustainability of the Pontificia Universidad Católica de Chile, the workshop was chaired by Dr. Rubén H. Roa-Ureta and Dr. Rodrigo Wiff, and attended by individual researchers and technical experts who were invited to contribute to address knowledge gaps and participate in discussions to achieve the workshop goals.

The main purpose of the workshop was to make advances toward the development of a regional stock assessment to serve as the basis for scientific advice for the sustainable harvest of the *I. argentinus* stock by all fleets operating in both, national jurisdictions and international waters. The main fleets according to landings volume are Argentinian operating in national waters and Asian fleets mostly operating in international waters. Total landings (and those of the main fleets) have entered a period of wide fluctuations after growing to over 1 million tonnes in 2000.

Participants described the type of data that were collected in the national jurisdictions of Argentina, Falkland/Malvinas waters, Uruguay and Brazil, and that were available for the creation of a regional database for stock assessment. Data collection by Asian fleets was determined to be useful for stock assessment from publications of Asian scientists and from knowledge of the jumbo squid fishery in the South East Pacific, where practically the same Asian fleets as those operating in the South West Atlantic fish for the jumbo squid.

A conceptual model of the spatial functioning of the *I. argentinus* across the entire region was developed as a working hypothesis. Strong evidence supporting the existence of coastal and oceanic segments of the stock led to the hypothesis that the stock is composed of several smaller coastal sub-populations that complete their short life cycle in a West-East orientation while a larger subpopulation completes the life cycle in the South-North orientation over much larger spatial scales.

A description of the difficulties experienced on the development of regional stock assessment and management of the jumbo squid fishery in the South East Pacific under the umbrella of a well established regional management organization (South Pacific RFMO) led to the conclusion that the creation of such organization in the South West Atlantic to assess and manage the *I. argentinus* would face enormous challenges in the mid-term. Facing this hurdle, the plenary session discussed the potential to use market forces to provide incentives to companies registered in different jurisdictions to share data relevant to stock assessment with a group of independent experts. These experts would develop the stock assessment model and apply it, and then they would provide scientific advice to achieve sustainable harvest rates to all stakeholders. This idea was identified by all participants as a viable interim solution, since global supply chains are among the stakeholders whose operations may be more impacted by the lack of science-based management. It was further considered that the development of a scientific basis for an adequate management of the entire stock may serve the broader goal of triggering the development of a Regional Fisheries Management Organization in the South Atlantic or, at a minimum, facilitate constructive inter-governmental discussions to advance towards joint managements agreements that can ensure sustainable exploitation of the *I. argentinus* stock in the South West Atlantic.

To move forward, lines of communication with fishing fleets of the different nationalities targeting *I. argentinus* should be established to evaluate the feasibility of proposing data share mechanisms to conduct an independent regional stock assessment. Once these lines of communication are established work should focus on collecting and harmonizing the data provided by these fleets and then develop stock assessment methodologies that would run with the harmonized databases.

2. Introduction

The fishery for the Argentinian shortfin squid (*Illex argentinus*, illex for short) is one of the largest invertebrate fisheries of the world. It has produced over a million tonnes of landings in some years (Fig. 1). In the last 5 years of FAO's FishStat database, ships from 12 countries appear as participating in the fishery in both, coastal states and international waters. Ships flagged by China, Argentina, Taiwan, and South Korea take the larger fraction of the annual total, although ships with flags of Spain, Falklands/Malvinas and Vanuatu, also take large catches. The illex fishery in the South West Atlantic and the jumbo squid fishery in the South East Pacific comprise between one third and almost one half of global cephalopod catches [1]. Clearly the illex fishery in the South West Atlantic is an important fishery for the food security, the health of ocean ecosystems and for the integrity of supply chains to several markets.

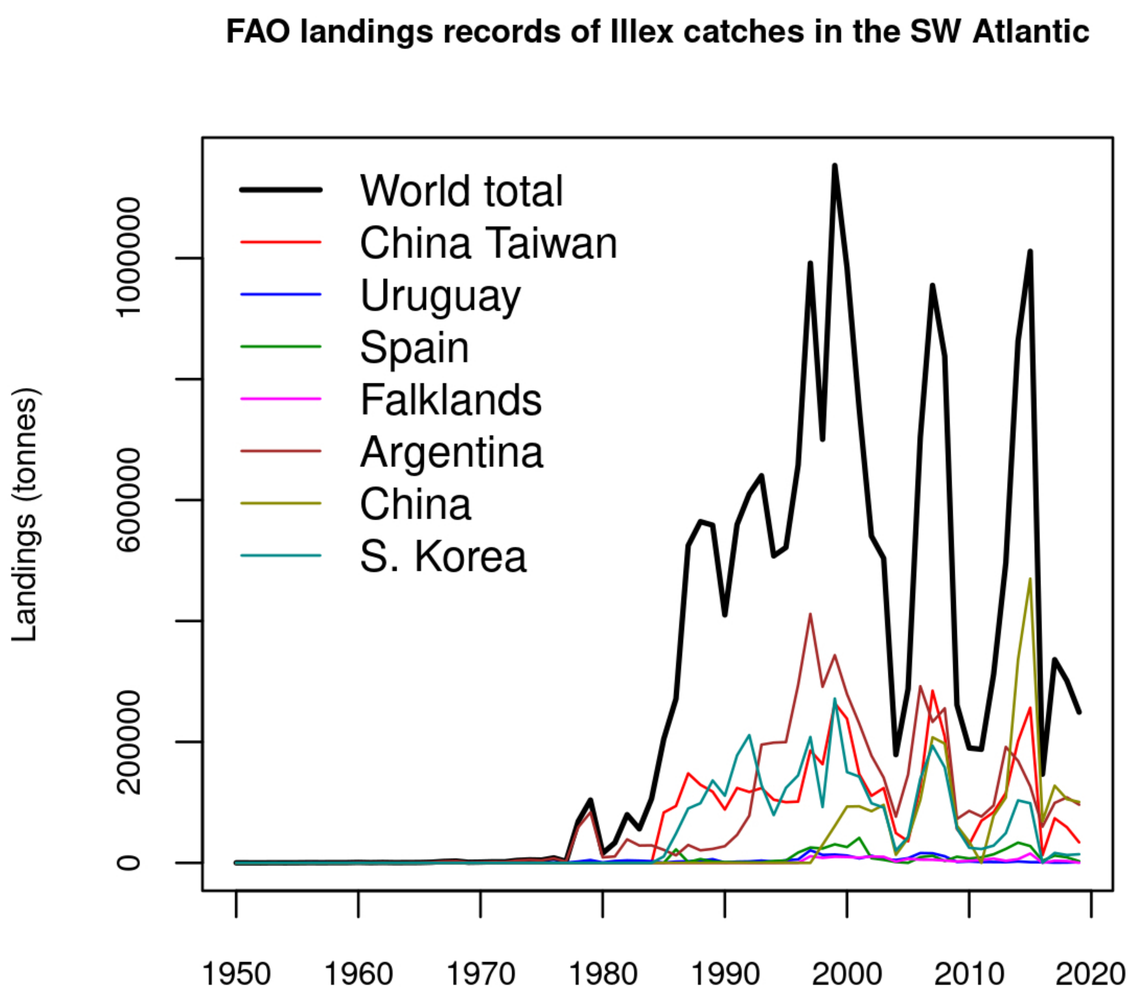

Figure 1: Landings of illex in the SW Atlantic as recorded by FAO.

Arkhipkin et al. [1] have recently raised the issue of lack of integrated management and stock assessment across the region, both in the jumbo squid fishery and the illex fishery. Winter [7] presented stock assessment results for illex using Argentinian and Falkland/Malvinas Islands data with survey estimates and depletion models for 2019. This assessment did not include catches of the largest three fleets, all flagged by Asian countries. Other scientists have presented partial assessments with China-Taiwan data [2] and data from China flagged fleets [5]. Although these results provide a benchmark of biomass and other parameters of interest, they are only partial in nature and ignore the major issue of the functioning of the stock across the whole region. Knowledge of the stock's spatial dynamics across the whole region is essential for scientific management and requires the use of data from all fleets to produce a region-wide assessment.

The jumbo squid fishery is overseen by a regional body with scientific mandate and capacity while the illex fishery lacks any form of coordinated and comprehensive monitoring and management. As a result, Arkhipkin et al. [1] fear that uncontrolled catches mostly in the high seas will make the illex stock susceptible to overfishing. They propose the creation of a multi-national advisory forum that would collect data, conduct regional-level stock assessment, and offer management advice based on sci-

entific results. Within this context, the workshop naturally evolved into discussing innovative solutions to achieve the ultimate purpose of conducting region-wide stock assessment of the illex stock in the South West Atlantic.

In the time series of landings recorded by FAO (Fig. 1), a pattern emerges whereby landings increase steadily to over a million tonnes during the first 25 years (1975 to 2000) of the fishery and then start to experience wide fluctuations over the remaining 20 years. This happens to total landings and the landings of the four largest fleets (China, Argentina, South Korea and China Taiwan). This is consistent with previous research showing that cephalopod stocks have a tendency to instability that is built-in their population dynamics though it is triggered by fishery removals [6]. Fluctuations such as those observed in the illex fishery landings indicate that fishery removals have reached a magnitude that alters the population dynamics of the stock, adding urgency to the need to assess the status of the stock.

3. Location and Agenda

The workshop took place at the Estación Costera de Investigaciones Marinas (ECIM) in Las Cruces, Valparaíso region, Chile. ECIM was founded in 1982 when the Pontificia Universidad Católica de Chile (PUC) acquired a property in a rocky outcrop in Las Cruces. ECIM is known for being the first no-take marine reserve area in the world, eventually leading to propose a novel resource management system for benthic stocks, which is internationally known as Territorial User Rights for Fishers (TURFs).

Since its beginnings, ECIM has provided support for researches from the main campus in Santiago, and it is well known as a world class marine laboratory with outstanding facilities for hosting scientists and students who work on diverse topics of marine sciences. ECIM provided the participants the perfect venue for hosting this workshop in a quiet and inspiring working environment.

Workshop participants included the workshop conveners, scientists invited as government representatives and experts participating on a strictly scientific collaborative status. Government representatives came from the Falkland/Malvinas Islands, Uruguay and Chile.

Table 1: List of contributors

Name	Institution
	Conveners
Rubén Roa-Ureta	Chair, Independent consultant, Spain
Rodrigo Wiff	Co-Chair, Pontificia Unversidad Católica de Chile, Chile
	Observers
Renato Gozzer	Sustainable Fisheries Partnership, Peru
Stefany Rojas	Sustainable Fisheries Partnership, Peru
Pedro Ferreiro	Sustainable Fisheries Partnership, Spain
Manuel Martinez	Sustainable Fisheries Partnership, Chile
	Government representatives
Alexander Arkhipkin	Falkland Islands Fisheries Department, Falklands Islands (Islas Malvinas)
Ignacio Payá	Instituto de Fomento Pesquero, Chile
Daniel Garcia	Dirección Nacional de Recursos Acuáticos, Uruguay
Luis Orlando	Dirección Nacional de Recursos Acuáticos, Uruguay
	Contributed documents*
Christian Ibáñez	Universidad Andres Bello, Chile
Rodrigo Silvestre	Federal University of São Paulo, Brazil
Augusto Crespi-Abril	Universidad Nacional de la Patagonia San Juan Bosco, Argentina

* These are scientific contributions that do not represent any jurisdiction

The organisers invited researchers and representatives from China and Taiwan, namely **Dr. Gang-li** from Shanghai Ocean University, and **Dr. Chia-Ying Ko** from National Taiwan University. **Dr. Gang-li** participates in meetings of the South Pacific Regional Fisheries Management Organization (SPRFMO) as a representative of China and had led the working group on the flying jumbo squid. Despite their expressed interest in the topic of the workshop these renowned experts declined the invitation due to various reasons, including restrictions connected to the COVID19 pandemic. Nevertheless, these experts expressed their interest to be informed of documents resulting from the workshop and to eventually join in possible future meetings, to which the organizers agreed. The workshop was conducted in five sessions and had a duration of two and a half days. The final agenda adopted throughout the meeting was as follows:

Table 2: Adopted agenda

	Day 1
09:00 - 9:20	Sergio Navarrete (ECIM Director) • Welcome to ECIM and safety measures
09:20 - 11:00	R. Roa-Ureta • Participants, Agenda. • Workshop motivation and topics to cover.
11:00 -11:20	*Coffee Break*
11:20 - 13:30	Fishery of *I. argentinus* in the Falkland Islands (Malvinas)
13:20 -14:30	*Lunch Break*
14:30 - 15:45	Biology and data availability of *I. argentinus* in Argentina
15:45 -16:10	*Coffee Break*
16:10 - 17:10	Genetics and population units in squids
	Day 2
09:00 - 9:30	R. Roa-Ureta • Summary day 1. • Agenda day 2.
09:30 - 10:30	Biology and data availability of *I. argentinus* in Uruguay.
10:30 -11:00	*Coffee Break*
11:00 - 12:00	Biology and data availability of *I. argentinus* in Brazil.
12:00 - 13:00	Plenary discussion of biology of *I. argentinus*.
13:00 -14:20	*Lunch Break*
14:20 - 15:20	Regional management of flying jumbo squid, overview and advice on the context of *I. argentinus*.
15:20 -15:40	*Coffee Break*
15:40 - 17:00	Plenary discussion for stock assessment.
	Day 3
09:00 - 11:00	R. Roa-Ureta • Summary day 2. • Plenary Discussion.
11:00 -11:20	*Coffee Break*
11:20 - 13:00	Workshop conclusions.
13:00 -15:00	*Lunch and workshop closure*

4. Sessions

4.1 Day 1

Motivation for the workshop

- The first day started with a welcoming introduction to ECIM from its director, Dr. Sergio Navarrete. A brief history of ECIM was given along with safety measures in case of emergency.
- Each participant started giving his or her background and this served as personal presentation and first step into getting to know each other. The main goal for this workshop was established as to achieve a regional stock assessment of the illex stock in the South West Atlantic to provide scientific advice that can serve as the basis for sustainable exploitation of the stock.
- The chairman gave a presentation of aspects of the population dynamics and productivity of the illex stock using illex landings data from FAO databases. He gave two scientific motivations to the sessions that will follow: (1) what recent wide fluctuations in landings reveal about the population dynamics and productivity of the stock and (2) how the stock's population dynamics worked in the spatial context of the region, from southern Brazil to the southern tip of South America. In connection with (1), he argued that the wide fluctuations observed in landings in the last 20 years were the result of fishing mortality during the past 25 years and intrinsic properties of the stock that make it susceptible to unstable dynamics, meaning that fluctuations in landings reflect underlying fluctuations in abundance. The chairman presented the Pella-Tomlinson surplus production model,

$$B_y = B_{y-1} + f(\boldsymbol{\theta}, B_{y-1}) - C_{y-1}$$
$$f(\boldsymbol{\theta}, B_{y-1}) = rB_{y-1}\left(1 - \frac{B_{y-1}}{K}\right)^{p-1}$$

– B is stock biomass
– y is year
– f is the biomass production function
– $\boldsymbol{\theta} = \{K, p, r\}$ is a set of parameters that are unique to the illex stock and determine its productivity
– C is the annual total catch by all fleets operating in the fishery
– r is the intrinsic rate of population growth
– K is the carrying capacity of the environment
– p is the symmetry of the production function

which is a generalised version of the widely used family of surplus production model. In the context of this model, the chairman explained that the intrinsic rate of population growth (r in the equation above) will trigger instability and chaotic dynamics in animal populations once it passes a maximum value, this value being a threshold separating stable from unstable dynamics. Then he explored the consequences of unstable dynamics in the derivation of biological reference points (BRP) to determine sustainable harvest rates. He argued that as a consequence of unstable dynamics, unstable stocks such as possibly the illex stock, cannot be managed with conventional BRPs derived from the maximum sustainable yield (MSY) but instead have to be managed with BRPs derived from the more general surplus production concept of **latent productivity**. In connection with (2) the chairman asked whether the stock had a predominant north-south dynamics such as larval growth and survival in the northern part of the geographical range, somatic growth and reproduction through migrations to the southern part of the range, and then spawning and larval birth once again in the northern part. Essentially, the second major topic to address towards a regional stock assessment was how the stock completed its life cycle in the extension of its geographical range.

- Pedro Ferreiro gave a presentation of the aim of the Sustainable Fisheries Partnership (SFP) regarding the interest in taking part in the workshop as observers from a non-for-profit organization that works in partnership with the seafood industry that process, imports and commercialize the catch of illex. The main aim of SFP is to use the market to improve sustainability in fisheries, from both the stock and market viewpoints. SFP works with large retailers in Europe and the U.S.A. to improve sustainability in fisheries. From a business perspective, companies operating over a well-managed stock are in a better position to attract suppliers and investments in their companies. If many of these companies used illex as raw material, then sustainability of this stock is then translated into low risk for investors. Ferreiro also emphasised the reputation gains for enterprises up the supply chain when they support sustainable practices and fisheries policies, highlighting corporate social principles that are conducive to sustainable and well-managed fisheries.

Fishery of *I. argentinus* in the Falkland/Malvinas Islands
Dr. Alexander Arkhipkin

- A general overview of the biology and fisheries of illex in the Falkland/Malvinas waters was presented. The main topics were related to demography, migrations, population structure, data availability, stock assessment methods and monitoring of high sea fishing vessels.
- Population structure in the spatial domain seemed to consist of a single population unit with a large stock that completes its life cycle from southern Brazil to southern Falklands/Malvinas and at times happens largely in the high seas.
- The first discussion took place on how to regulate the fishery of illex in the south Atlantic. The main outcomes from this discussion are that data collection and stock assessment could be stored and handled by a third party (such as an NGO) so as to avoid geopolitical challenges linked to territorial disputes. Discussions were held about the involvement of scientists from coastal states and the risk that such engagement may pose to ensure wide adoption of the stock assessment results. During this session, the idea of creating databases and conducting the stock assessment with support from independent experts was first formulated
- One of the foreseen problems in the above discussion is transparency in stock assessment and data sharing.

Fishery of *I. argentinus* in Argentina
Contributed document

- A report containing an overview of the illex fishery in Argentina was provided by the scientific advisors. Information regarding reproductive biology, connectivity, distribution, fisheries oceanography and data availability was presented.
- Smaller stocks, parts of the larger population, occupy coastal areas inside the Argentinian Exclusive Economic Zone and may complete its life cycle in a East-West direction instead of a South-North direction. Data from this part is sparse due to illex being a by-catch of trawlers.
- Coastal parts of the stock may act as buffer and improve resilience because spawning occurs and may replenish depleted parts that complete their life cycle in the South-North direction.
- This contribution led to hypotheses of the spatial functioning of the stock that may have a strong influence on the mathematical structure of any stock assessment conducted on the stock, and therefore on scientific management for sustainability. These hypotheses coalesced into a working hypothesis of the stock's population dynamics in space across the region during the plenary session at the end of the workshop.

Genetics and population units
Contributed document

- Recent advances in fisheries science highlight the importance of genetics in squids populations. The importance of genetics in fisheries science is not just stock unit but genetic flows to infer, for example, migrations. Population with larger abundances have higher genetic diversity.
- Genetics studies from the late 90s indicate that there could be 2 populations of illex in the south Atlantic. However, new data using recent genetic techniques indicate that the illex stock comprises just one population on its entire distribution in the South West Atlantic.

4.2 Day 2

Generalities

- The chair summarised the main points of presentations and discussions held on the first day of the workshop. He also provided an examination of two papers with assessments of illex by Chinese (Schaefer surplus production with time-varying K) and Taiwanese (geostatistics of fisheries data) scientists. The first paper [5] used the simple Schaefer surplus production model (as in the equation above for the Pella-Tomlinson model with p assumed to be equal to 2) with environmental influences, covered the period of 2000 to 2010, and did not include catches by Argentina and Uruguay. Authors fitted their model to catch per unit of effort using the number of vessels operating per month as their measure of fishing effort. They concluded that the stock was not experiencing overfishing and that the stock was not overfished. The second paper [2] assessed the stock using estimation techniques for surveys (geostatistics) instead of stock assessment models, used only Taiwanese data, included locations in coastal state waters (Argentina and Falkland/Malvinas Islands) as well as in international waters, and covered a period spanning 1985 to 2013. The authors concluded that the stock had a healthy status over the entire time series. Participants in the workshop expressed doubts about these results due to several shortcomings of the data and the modelling approaches that each of those teams employed. For instance, Jintao et al. [5] selected an estimate of MSY of between 351,600 and 685,100 tonnes, or 518,000 tonnes as the median, from their Schaefer model, while the total catches over the region (Fig. 1) have been larger than their median MSY over most of the years of their time series and yet the stock has been found to be sustainably fished. This appeared to be contradictory. The work by Chang et al. [2] raised concerns regarding their data because (1) it was not explained how the authors turned catch per vessel-day into catch per area (e.g. km^2), which is necessary for geostatistical estimation of biomass, and (2) their annual catch data are much lower than FAO records for the region, among other issues. Nevertheless, these papers by Chinese scientists clearly showed that the data from Asian fishing fleets (China and China-Taiwan) is collected by researchers in a manner that is conducive to stock assessment. In summary, it seemed to the working group that (1) the issue of the regional stock assessment of the illex stock in the South West Atlantic has not yet been resolved in a comprehensive manner, both from the data coverage and the method of assessment points of view, but that (2) the data necessary to undertake a comprehensive, regional stock assessment, are available from all fleets.

Fishery of *I. argentinus* in Uruguay
Dr. Luis Orlando

- The catch by Uruguayan fleets is quite significant (10,000 tonnes) although it is a by-catch of trawlers targeting finfish.

- Uruguayan data on illex is opportunistic rather than regular, lacks biological information in recent years, and links to a bilateral commission with Argentina because the fishing happens in the Argentine-Uruguayan Common Fishing Zone.
- Nevertheless, data from Uruguay seems sufficient to conduct stock assessments, including data that is stored by individual scientists.

Biology and demography of *I. argentinus* in Brazil
Contributed document

- Illex is mainly fished as bycatch in southern Brazil by trawlers targeting finfish species.
- In Brazilian waters the catch of *I. argentinus* presents two distinct groups differing in body size, one larger, migrant group captured at deeper waters (700 m) and a smaller resident group captured in shallower waters (250 m).
- Data regarding catch, effort and some biological attributes are available and public. Some data relevant to stock assessment are held by local scientists but could be available in the context of regional management of this species and/or regional stock assessment.

Regional management of the flying jumbo squid, overview and advice on the context of *I. argentinus*
Ignacio Payá

- A history of the South Pacific Regional Fisheries Management Organization (SPRFMO) in the South East Pacific reveals that it takes a very long time, even a decade, to reach the necessary coordination to conduct an official stock assessments, something that still is not achieved in the jumbo squid fishery.
- Even after all that time, there is no solid knowledge of basic aspects of the life cycle of the jumbo squid.
- On a more positive note, in the case of illex a convention or any other form of international agreement can be more effective than in the flying jumbo squid fishery because it would only deal with only one species. In the case of SPRFMO, the most important species is the jack mackerel and therefore, other species have been considered as of less relevance.

Figure 2: A working hypothesis of the spatial functioning of the stock as agreed by workshop participants. Several smaller coastal sub-populations complete their life cycle in West-East orientation while a larger sub-population completes its cycle in South-North orientation. There is a degree of connection between coastal and oceanic sub-populations.

4.3 Day 3

Plenary Discussion
The following topics were considered as most pertinent and were discussed at length during the plenary session. They are the agreements on the way forward to achieve the purpose of conducting regional stock assessment, offer scientific advice for sustainable fishing, and then support relevant stakeholders and supply chains.

- Basic biological processes such as age and growth and sexual maturation and ecological processes such as spatial distribution are already well known for the illex stock in the South West Atlantic.
- There are coastal and oceanic segments of the population, with several coastal populations completing the life cycle in the West-East orientation, and a larger oceanic population completing the life cycle in the South-North orientation (Fig. 2).
- The stock assessment model should be of the depletion type as this methodology has proven to be useful for the fast life history of squids.
- Biological reference points should be consistent with possible unstable dynamics and it is recognized that this is a methodological aspect that should be explored.
- The development of a dedicated regional management organization for the purpose of informing resource users of sustainable harvest rates and warn the users about the risks of overfishing of the illex stock is expected to be slow and face many challenges. Therefore, participants did not consider that establishing a regional management organization will aid to reduce uncertainties of the present and future outlook of the resource.
- An innovative idea is presented to take an alternative interim route to achieve the purpose of conducting a regional stock assessment: passing industry fisheries data relevant to stock assessment to a board of independent experts, under strict confidentiality arrangements, so that an independent evaluation of the stock's status become available.
- The board of independent experts would not be connected to any of the stakeholders of the fishery and their work would be peer-reviewed by other independent experts to guarantee its quality.
- The board of independent experts would conduct stock assessment and would deliver scientific advice on how to best manage the fishery to support its sustainability.
- This initiative may help to create additional incentives and advantages to the participating industry players.
- At the starting point the group of independent stock assessment scientists would require the support of a facilitator connecting industries with the board of independent experts.

5. Conclusions

In order to advance to the goal of sustainable harvest of the *I. argentinus* population in the South West Atlantic, participants discussed and agreed upon the need to build a database for stock assessment and then develop a stock assessment methodology of the entire population across the region.
This assessment will use as a minimum all the available data from all or at least the major fishing fleets that are operating in the South West Atlantic (FAO Major Area 41). The main fleets are Argentinian, Chinese, China-Taiwanese, and South Korean Flagged fleets , and the other relevant fleets are flagged by the Falklands/Malvinas, Spain, Vanuatu, Uruguay and Brazil.
The stock assessment methodology will take into account the complete spatio-temporal dynamics, taking into account our working hypothesis of coastal and oceanic sub-populations, with specific connections between population sub-units.

Workshop participant identified four areas that need to be addressed:

1) Catalog available fisheries data from fishing companies.

- Daily catch by commercial size categories.
- Daily fishing effort.
- Daily location (Argentina, China, China-Taiwan, South Korea, Brazil, Uruguay, Falklands/Malvinas, Spain and Vanuatu flagged fleets).

2) Basic biology and spatio-temporal structure of the population.

- Compilation of all available information of basic biology and spatial structure from Southern Brazil to Southern Patagonian shelf.

- Test hypotheses of spatial functioning that would inform the stock assessment model. Participants agreed upon an initial working hypothesis where coastal subpopulations function as separate reproductive units connected to a major unit that completes its life cycle in oceanic waters (Fig. 2).

3) Stock assessment and biological reference points.

- Follow the general depletion model approach but aim at in-season assessments using the fine time resolution of all databases in the different areas.
- Connect the output of depletion models with surplus production models or other models that describe the dynamics of the stock across years.
- Attempt to introduce biological composition to the depletion approach by considering distinct phenotypes, for instance at the northern margin of the distribution (Brazil), but examine that aspect over the whole region.
- Target and limit biological reference points (BRP) need to be developed or adopted, such as MSY, escapement biomass, exploitation rate, latent productivity, and possibly others.
- Use a communication tool to pass the advice to stakeholders (for instance, the Kobe plot).
- Define harvest control rules that given the results of stock assessment and the BRPs achieve sustainability (potentially considering also stability in catches).

4) Way forward.

- Establish a board of independent experts to conduct the regional assessment.
- Prepare a short document or presentation to approach the seafood industry with the idea of the board of experts and stock assessment at the regional level.
- Establish contacts with seafood industry actors with interest in collaborating by providing the data.
- Define strict confidentiality clauses to protect commercial interests.
- Establish a peer-review system to vet and improve the assessment.
- Define new data necessary to fill gaps and correct weaknesses in the stock assessment.
- Make a reasonable and achievable workflow and time frame on a monthly time step that gradually builds up.

5) Next steps

- Define the board of independent experts which could be named the Independent Scientific Committee for Illex (ISCI).
- Establish a support group of scientists from the region and elsewhere that support the board of independent experts.
- Organize a benchmark workshop to agree on the basic assumptions of the structure of the stock, the stock assessment methodology and BRPs.
- Prepare an Memorandum of Understanding describing the principles of the cooperation to achieve the goal.

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6. Outreach to the seafood industry

6.1 Introduction

The workshop did not discuss specific details of the appeal to the seafood industry that was mentioned in the second bullet point of Way forward. This document would seek to obtain the necessary data for regional stock assessment directly from fishing companies. Nevertheless, here the organizers present some elements that such a document may contain and that are open to comments and contributions by the participants in the workshop.

During discussions of the Falkland/Malvinas presentation and in the Plenary, the idea emerged that the seafood industry may become a direct participant in the scientific process by providing the necessary data to conduct a regional stock assessment. This innovative idea emerged because of the difficulties of the traditional solution, which corresponds to setting up a transnational management body.

A transnational management body requires a long time to form and mature. In the Southern East Pacific the South Pacific Regional Fisheries Management Organisation (SPRFMO) started in 2006, while the jumbo squid fishery started in earnest in 2016, with multiple fleets fishing in national jurisdictions and international waters. Nevertheless up to this time the SPRFMO has not produced the first official regional stock assessment of the jumbo squid stock across the entire region.

An evaluation of the status and sustainable harvest rates of the illex stock in the South Western Atlantic at the regional level is needed sooner than the time required to build a transnational management body. Eventually, the idea emerged that the data necessary for a regional stock assessment could be obtained directly from fishing companies.

This idea is viable because the stock assessment method that workshop participants are specifying, depletion models, do not require data generated by scientific installations such as biological laboratories or time doing surveys at sea. Depletion models work with fishing operational data exclusively.

The seafood industry could help in this endeavour by providing incentives to fishers that cooperate with this scientific initiative. In the midterm all parties would benefit from scientific knowledge to coordinate harvesting rates of the various fleets.

6.2 Rationale

There is substantial uncertainty in connection to the status of the *Illex argentinus* stock in the South West Atlantic. No scientific assessment has yet included the whole fishery, encompassing national waters and the high seas. A worrying sign is that starting at the turn of the century, landings have become extremely variable, swinging back and forth from lows of around 200 thousand tonnes to highs of nearly one million tonnes. These very wide fluctuations could be the preamble to a collapse that would disrupt the seafood sector of national economies and supply chains to international markets, as well as food security, from the second largest invertebrate fishery of the world.

Similar to the illex fishery, many squid fisheries around the world have experienced fast growth in landings and subsequent wide fluctuations and decline, some of them suffering collapsed landings. Fig. 3 shows the total landings of all squid species fished around the world and the 17 largest fisheries as reported by FAO in the last seven decades. Total landings increased steadily from 1950 to 2005 and then they have stabilized around three million tonnes. Unfortunately, nearly all those stocks remain without scientific stock assessment of the complete population. Of all time series of landings portrayed, only the newest fishery (schoolmaster gonate squid), started in 2005, shows growth in landings (the other panel showing increased landings is common squid nei, which contains disparate fisheries from all over the world from jurisdiction that do not specify the species), three single-species series show certain stability, and the remaining ten fisheries, marked by dark red panels in the figure, are either collapsed, with current landings much lower that the historical maximum, or experiencing wide fluctuations.

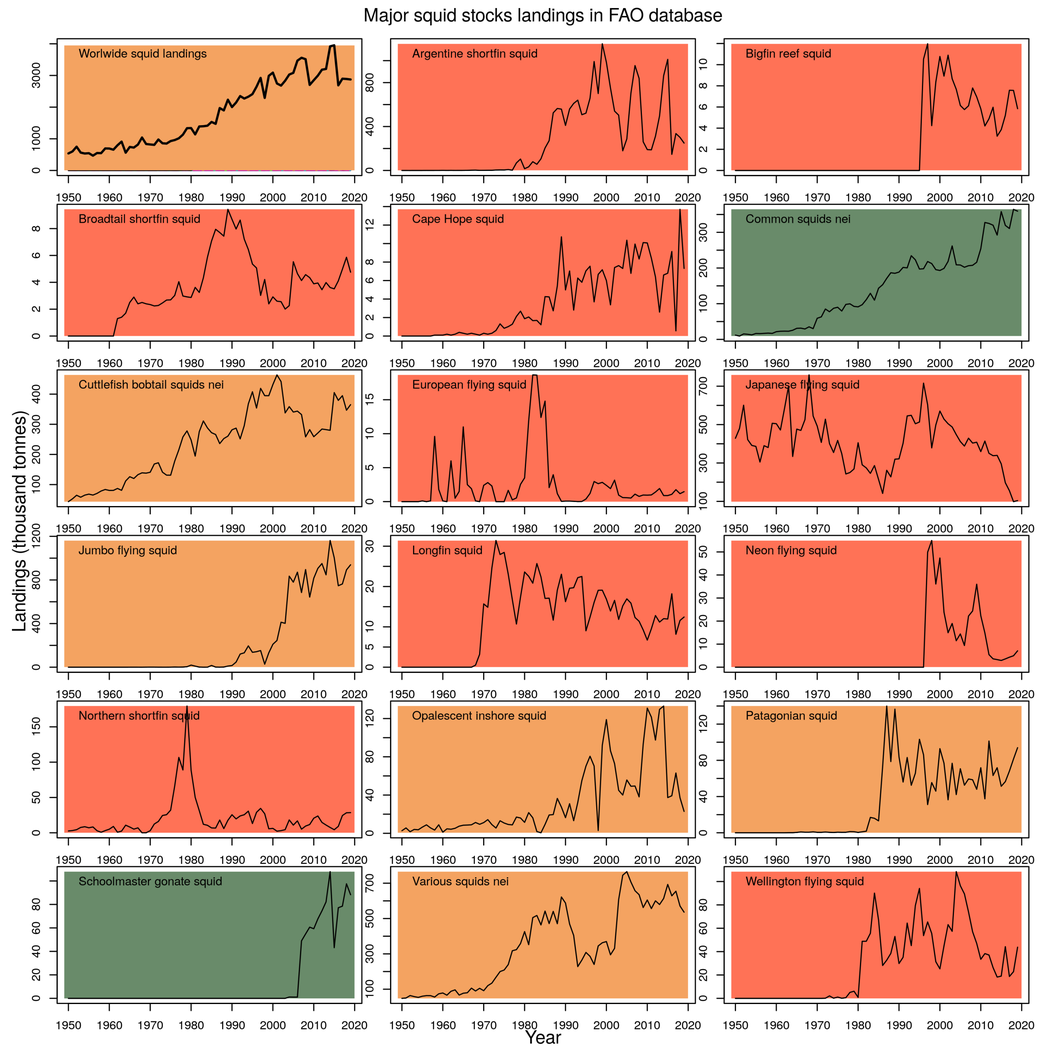

Figure 3: Worldwide aggregate landings of squids and landings of the 17 largest squid fisheries in the world according to FAO databases over the last 7 decades. Panels marked in dark green are fisheries with growing landings, those marked in dark yellow have stable landings in the last few years, and those marked in dark red have widely fluctuating or collapsed landings in the last few years.

The case of the northern shortfin squid is particularly informative. This squid (*Illex illecebrosus*) is closely related to illex and it is fished in the North-West Atlantic by two American fleets. The fishery collapsed in four years (1979 to 1983) and has never recovered, remaining in a low productivity status despite substantial efforts by US scientists to study and recover the stock through active scientific management [4]. We fear the same undesirable outcome awaits the illex fishery in the South West At-

lantic, which even though it is probably more resilient than *I. illecebrosus*, it faces the serious disadvantages of being fished by fleets from multiple countries, on national and international waters, and lacking any effort so far to assess the stock scientifically over the entirety of its extension.

The economic consequences of a collapse in the illex fishery in the South West Atlantic are also much more significant than the collapse of the *I. illecebrosus* fishery in the North-West Atlantic. Maximum landing in the illex stock are ten times higher than the maximum landings reached in the *I. illecebrosus* fishery. The illex stock contributes to exports of a large South American country (Argentina) and is a major item for processing in land and at sea of three Asian nations, including China, which export illex products to Europe and the U.S.A. [3]. Similarly, squid cleaning, processing and exporting nations lacking direct access to large squid stocks, such are Spain and Morocco, rely on large squid resources like Illex to maintain a thriving seafood industry. Although the value chain of illex products are difficult to determine due to scarce published data, preliminary calculations suggest that primary harvesters gross profit margins vary between 32% to 44%, processors gross profit margins range from 19-34%, and wholesale margins range from 14 to 67% [3]. These preliminary calculations imply large economic turnover considering the very large amounts of landings in some years.

These considerations emphasize the fact that a probable collapse of the illex fishery, due to un-coordinated exploitation and extremely wide fluctuations in landings in the absence of a scientific assessment of the status of the stock, will have negative economic and food security consequences across several jurisdictions, from South America to Asia, Europe and the U.S.A.

6.3 Data specifications

We understand that data useful to conduct a scientific analysis of the stock over the whole of its spatial distribution, are available in various sources, including government research centers and the fishing industry itself.

Fishing industry data that are necessary to conduct the proposed regional-wide stock assessment comes in two classes.

1) The first class is simple global input and output data, meaning a measure of the work put into fishing and a measure of the yield obtained, respectively. For instance, industry may have records of the volume of catch in weight for every fishing haul of each of their ships. These are input and output data, catch in weight per haul, where the haul itself is the count of input and the catch in weight is the count of output. Ideally, these data are at the finest possible resolution, for instance haul by haul, although data that have some degree of aggregation are still useful, for instance data aggregated by fishing trip or by day or week of fishing. These input and output data at best should extend for many years, possibly since start of operations: the longer they extend, the more solid the scientific results.

These input and output data would ideally be a complete count of all operations, not a sample. If that is not feasible, it is still possible to conduct a solid stock assessment with less than complete data under certain conditions.

The scientific analysis would pool all data into time intervals, for instance into total inputs and total output per week of fishing, thus losing all individual information. Therefore, scientific work with these data would not reveal commercially valuable industry information.

2) The second class of data are necessary to calculate the mean weight in kg of individual squids captured by the fleets by time step. This is necessary to transform catch in volume to catch in numbers of squids and run mathematical models based on numbers. The necessary data are the volumes of catch per size/caliber categories of squid with date of capture. These size/caliber data can be a small to moderately large sample, taken over a few seasons and well spread inside the season.

With these two classes of data, scientists have developed robust scientific methods that deliver useful information about the status of the stock and the best (meaning maximum) stable harvest rates [6]. Data acquisition would be undertaken under confidentiality requirements and scientists would provide data templates to facilitate the process.

Additional data, not necessarily used in the stock assessment but useful as collateral information, are geo-location of input and output data. Visualization techniques applied on these data help make adjustments in the stock assessment model, such as including movements of parts of the stock in and out of sub-regions.

6.4 Goal

Using aggregated fisheries data from fishing companies and based on the conceptual model in Fig. 2, we propose to conduct an independent stock assessment of the depletion type whose purpose will be to determine the status of the stock and calculate regional sustainable harvest rates, as well as other reference values, of the *I. argentinus* population in the entire South West Atlantic (FAO Major Area 41), so resource users can work together with state authorities to achieve consensus on harvest strategies aligned with sustainable harvest rates.

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