South Pacific Regional Fisheries Management Organisation

SPRFMO SC 2ND SQUID WORKSHOP REPORT

5-6 October 2019
Havana, Cuba

SPRFMO SCW8 Report 2019

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Contents

SPRFMO SCW8

Report of the 2019 SPRFMO Squid Workshop

Havana, Cuba, 5-6 October 2019
Adopted 11 October 2019 09:45 am

1. Welcome and Introduction

1. The Chairperson for the Scientific Committee Squid working group, Dr Gang Li, opened the meeting and proceedings and welcomed all the participants. A List of Participants is available as Annex 1.

2. Administrative Arrangements

2.1 Adoption of Schedule

2. The Chairperson proposed a detailed agenda to the working group. No detailed agenda was available before the workshop. An agenda is available in Annex 2

3. The Chairperson sought proposed changes to the agenda and presented a proposed schedule. Some suggestions were raised and accepted.

4. The workshop asked for clarification on whether presentations would be made at the workshop. The Secretariat clarified that presentations would be made. It was then requested that some presentations be moved to later in the day to give presenters time to write presentations.

5. It was agreed that the invited expert would present document SC7-SQ02.

2.2 Meeting Documents

6. Meeting documents are listed and are presented in Annex 3.

2.3 Nomination of Rapporteurs

7. New Zealand offered to provide *Rapporteuring*.

3. Squid Workshop

3.1 Inter-Sessional Activities

8. An invited expert, Dr Alexander Arkhipkin, presented SC7-SQ02 on “Prospect of distribution and fishing of jumbo flying squid (JFS) off the Chilean coast in the 2019 season versus 2017-2018” on behalf of the authors.

9. Related to the studies available from 2011-2019, off the coast of central and south-central Chile, the jumbo flying squid specimens from the fishery between the years 2011-2016 appeared as an incoming generation from the open sea and then parallel to the coast with increasing modal size throughout the years.

10. During the years 2017-2019 the spatial distribution of the resource and fishery changed along with the size structure of the catch. In these years the fishing season was reduced to only the first 7-8 months of the year and, starting in 2017, the mean size was from 50-55 cm ML (mantle length). The 2018 season had similar timing and sizes of jumbo flying squid with a single pulse at latitude of about 37ºS and subsequently dispersed along the coast to the south (smaller quantities) and to the north (larger quantities). The ages of jumbo flying squid in both these years were generally older than 1 year (as in 2011-2016). Migration northward to the spawning area along the coast extended into the southern part of Peru from July-August. In 2019, main concentrations of jumbo flying squid appeared to move as a single pulse from the north through the areas which were very close to the coast, starting from 27ºS in February and concentrated in April-July at 35-36º40'S.

11. In 2019 the Chilean fishery encountered small jumbo flying squid specimens about 25-30 cm ML in February-March with a mode of 50 cm in August which was also shorter than normal. It is possible that the smaller size jumbo flying squid that entered the Chilean coast from February 2019 recruited from the October-November 2018 spawning in the southern coast of Peru. This group was also apparently predominant in the coastal fishery of southern Peru between May-August of 2019 based on preliminary available data collected by the industrial fleet. It was noted that artisanal fleet data were unavailable (however, the catch from the artisanal fleet was very small this year and in the last 3 years was focused on the northern area).

12. The workgroup inquired if the extent of data indicated that jumbo flying squid were migrating away from Chilean waters into Peruvian waters to spawn and then returning. A reference was made to the possibility that sampling is not fully representative and may have missed spawning in Chilean waters given that the females are only mature for a very short period of time and also wondered if there is data to support an alternative hypothesis of Chilean or high-seas spawning aggregations.

13. It was clarified that samples are taken year-round, and that there are a range of hypotheses that could be valid. They noted that this paper posed one alternative based on information collected from fishing activities, not from directed scientific surveys. Survey and information from other fisheries to date indicate that spawning is occurring outside of Chilean waters due to the lack of larvae, although review of survey information is ongoing. In Chilean waters, jumbo flying squid appear in November and stay until the following October. This timing is consistent with the hypothesis that squid leave Chilean waters to spawn.

14. Dr Arkhipkin explained that mature females are rare in the Chilean zone and the few existing observations may not prove that spawning occurs there since they can still migrate long distances to spawn. Therefore, the jumbo flying squid may be migrating from the north to feed in Chilean waters.

15. It was noted that mature males are found off the coast of Peru almost year-round with mature females being present, but only during 3-4 months a year. That means a high percentage of sexually mature males persists but functionally mature females are only available for a relatively short period. Therefore, estimating the effective spawning (due to actively reproductive females) requires sampling the area year-round.

16. The workshop discussed whether a lower reproductive output would be expected given the observed shift in size to smaller squid. It was noted that other studies have found that fecundity in smaller female squid is significantly lower (per unit biomass) than large squid. Thus, it was likely that recruitment could be lower from a stock of medium size squid.

17. It was clarified that the change in the distribution of fishing effort between 2017 and 2019 was the result of changes in squid abundance. The presenter noted that larger squid swim faster than smaller squid, which might explain why they migrate further south.

18. The workshop noted that the term “small” should be defined so that it is used in a standard way across presentations.

19. The workshop discussed if gear selectivity might be driving the size differences in squid caught in the Chilean fisheries, given that the Chilean fisheries are primarily midwater trawl compared to the Peruvian fisheries which use jigging gear. The presenter clarified that the data is from a number of sources, and also that the change in size has happened in the last three years, so is unlikely to be caused by any changes or differences in fishing gear.

20. There were no recommendations arising from this paper.

21. Peru presented SC7-SQ03 on "Changes in predominance of phenotypic groups of Jumbo flying squid and other indicators of a possible regime change in Peruvian waters". The jumbo flying squid *Dosidicus gigas* is a neritic-oceanic species widely distributed in the Eastern Pacific. It has a high phenotypic plasticity that is expressed through the presence of three population groups, distinguishable by their maximum size and the size at which they reach sexual maturity. The three phenotypic groups tend to have somewhat different distribution areas and environmental preferences, which may overlap partially, and the three groups are found in the northern part of the Peruvian Current ecosystem, within Peruvian national waters, although not necessarily at the same time and space.

22. Monthly biological and fisheries information on *D. gigas* caught during commercial and scientific research fishing operations in Peruvian waters was analysed, together with coastal sea temperature data since 1989. Changes in predominance of these three phenotypic groups in Peruvian waters were examined while trying to establish if the sea surface temperature could be used as an indicator of the most likely environmental driver of the observed changes in the predominance of the population groups of *D. gigas* in Peruvian waters, and its possible relationship with regime changes observed for other species. The information available indicates that at least one decadal or regime change has occurred in the predominance of the phenotypic groups of *D. gigas* in Peruvian waters in the last 30 years, and that possibly another one may be in the making in recent years.

23. The phenotypic groups that mature at small and medium sizes predominated in Peruvian waters during the decade of 1989-1999, identified as a warmer period. The phenotypic group that matures at large sizes predominated during more than a decade, between 2000 and 2016, identified as a colder period. And, since 2017 there are indicators of a possible shift into another regime, probably of shorter duration, with the predominance of the phenotypic groups that mature at small and medium sizes in coincidence with what is being identified as another warmer period. It is also noted that, in addition to the changes in the predominant body sizes, these decadal changes are having an impact on the catch rates and abundance indexes of *Dosidicus gigas*. Higher biomass abundance indexes and total catches occur when the phenotypic group maturing at large sizes predominates, and lower biomass abundance indexes and catches when the groups maturing at small and medium size are the ones to predominate. It is expected that this information will be of use in adjusting fisheries management strategies to make the best use of this important and fluctuating fishery resource, guaranteeing its sustainability.

24. The workshop requested clarification on the data sources, and also on how the information from the artisanal fishery is adjusted to allow for the variability in spatial distribution of the fishery and where the information comes from.

25. The presenter explained that during the first few years of the jumbo flying squid fishery in Peru most of the fishing was done by large industrial squid jiggers who were allowed to fish almost everywhere except for the more coastal areas, but this fleet stopped fishing in 2011/12. The artisanal fisheries started in the north, but have spread more widely in the last 8-10 years. The spatial distribution of the artisanal fleet that was presented is based on information on catch (not CPUE). There is some stratification in the observations, and in some months and years, larger squid may dominate in the northern areas or may dominate in central or southern parts in other years. There does not appear to be any trend or pattern in size frequency distributions between northern and southern areas.

26. The presenter clarified that they are confident that the trends seen are not thought to be affected by selectivity or fisher behaviour (driven by market preferences), and that industrial Peruvian squid jig vessels in Peru have been known to catch large squid.

27. There were no recommendations arising from this paper.

28. Peru presented SC7-SQ13 on “Notes on jumbo flying squid distribution in Peruvian national waters during 2018-2019”. Hydro-acoustic assessment surveys of pelagic resources carried out by IMARPE (Instituto del Mar del Perú) between 2018 and 2019 determined that jumbo flying squid has a wide distribution throughout the Peruvian national waters. Jumbo flying squid was found in scattered small areas of higher abundance beyond 20 nautical miles from the coast, mainly in oceanic Surface Subtropical Waters (SSW) and along the fronts where mixed SSW and Cold Coastal Waters (CCW) occur. Habitat preferences of jumbo flying squid appear to be highly flexible, reflected by the wide range of temperatures and salinities typical of their horizontal and vertical distribution, from the surface to 400 metres of depth, following the concentration of mesopelagic organisms jumbo flying squid feeds on. This confirms that this species has highly flexible habitat requirements and adapts easily to changing environmental conditions through its vertical migrations and constant search for food.

29. In response to questions regarding possible species identification issues, it was clarified that a multi-frequency acoustic system allows differentiation of squid from other species. This acoustic eco-trace identification is supported by on-site identification through fishing (using trawling and/or jigging) and plankton collections to confirm species identification and/or mix of the eco-traces seen acoustically. The presenter also clarified that the graphic that identified the centres of gravity refer to the overall distribution of squid found during the four acoustic surveys.

30. The workshop also queried whether the conclusion of the paper is driven by a change in the backscatter and not changes in target strength dependent on the timing of the survey. The presenter explained that they initially worried there would be interference with acoustic signal, particularly at night when there were more species around that squid were predating upon. They also worried if squid target strength would be different if they were full of food rather than hungry/empty. The data suggest that there is no issue with other species interfering with the signal or with the fullness of the stomach. The key consideration in these analyses is to make sure that there isn’t a difference in the night and day target strength or the acoustic signal of the eco-traces identified as being from squid that may require different interpretation of the data. Nevertheless, it was noted that with the current equipment, this can be checked during each survey.

31. There were no recommendations arising from this paper.

32. Chile presented SC7-SQ14 on “Environmental variability and abundance availability, size and condition of squid in Chile”. Jumbo flying squid is usually found in the equatorial region, and depending on environmental conditions, expands its range to the subtropical areas of both hemispheres. In Chile, jumbo flying squid abundance increased in 2002, but since 2011 it is one of the main fisheries of this zone. Since 2017, there have been important changes in this fishery. In the first half of 2019, artisanal catches have been minimal, while industrial catches have been maintained.

33. The objective of this work was to analyse the relationship between environmental variability and abundance, availability, individual size and the condition of jumbo flying squid in Chile and Peru. The following were reviewed:

- the biology, population dynamics and fisheries of squid at national and regional levels (FAO Area 87);
- indicators of their abundance and / or availability; and
- information on environmental variability at national and regional levels and historical information on the presence of jumbo flying squid in Chilean waters.

34. The information was reviewed to identify correlations between environmental variables and squid landings, squid lengths, physical condition, and spatial distribution. It was found that there were correlations with environmental variables including the Humboldt Current Index and El Niño events in a number of squid characteristics in different areas including changes in size, body condition, and areal abundance. The El Niño event in 2015-2016 generated a warming that produced waters of lower productivity, which activated the earliest maturation seen in squid which generated the group of intermediate sizes that were captured in 2019 by the industrial fleet. Changes in the squid abundance and the fall of squid size in the central-southern zone of Chile are consistent with the changes observed in Peru and the Gulf of California during the period of low productivity produced after El Niño event.

35. Enquiries were made on why there is no drop in squid abundance in November and December given the statement that squid arrive in November and leave the following December. The presenter clarified that the new cohort of smaller squid arrives at that time and keeps the biomass stable. It was also clarified that the industrial fleet only fishes from January to August each year, so there is no industrial fishing from September to December.

36. The effect of trophic factors relative to the jumbo flying squid population was discussed and it was noted that surveys of other resources continue to provide information on changes in relative stock productivity. However, to date, changes have only been identified in chlorophyll but other aspects of the ecosystem are being evaluated, including jack mackerel.

37. There were no recommendations arising from this paper.

3.2 Basic Biology

38. Peru presented SC7-SQ04 on "Protocol for biological and biometric sampling of jumbo flying squid in use in Peru". The paper described the methodological procedures for the biological and biometric sampling of *Dosidicus gigas* in use by IMARPE, including relevant materials and methods. This includes description of the types and methods of biometric and biological data sampling, required sample sizes and frequency, anatomical sampling, and sexual maturity stages for gonadal maturity determination.

39. A number of workshop participants confirmed that they also have protocols for biological sampling, but noted that they are likely to be different because the intent of each regime may be different (e.g. stock assessment vs. monitoring).

40. The importance of having a standardised template for biological sampling, particularly measuring of squid length and staging of gonads, and number of animals per sample was reinforced by A. Arkhipkin.

41. The workshop **recommended** that the development of a biological sampling protocol should be added to the SC squid workplan for the future.

42. The invited expert Dr Arkhipkin presented a talk on temperature effects on the duration of life cycle of the eastern Pacific jumbo squid *Dosidicus gigas*.

43. To reveal possible interannual variability in the life span, statoliths were aged from mature females belonging to two modal size groups (<490 mm and >500 mm mantle length) collected before (1991-1996), during (1997-1998) and after (1999-2011) the strong El Niño event in Peruvian waters. It was demonstrated that water temperatures encountered between the 3rd and 6th months of ontogenesis had the strongest negative effect on age. Together with weaker but significant negative effect coming from temperatures encountered during early life (1st -3rd months) and later ontogenesis (7th and 8th months), these temperature parameters (together with other environmental factors) were important to determine whether a given animal has a 1-year life cycle (matures early and attains small sizes), or 1.5-2 year life cycle (delayed maturation and large size). Appearance of the large form resulted in a substantial increase in population fecundity, and given favourable environmental conditions, drastically increased the abundance and especially biomass. Warmer temperatures at juvenile-early adult stage caused squid to mature earlier, and therefore complete their life cycle in 1 year at much smaller size, decreasing the population fecundity. The possible cause of a sudden increase in abundance of the large group of *D. gigas* in 2000-2001 was discussed. It was also noted that given the approximately 2 year life cycle of the large form with alternation of generations, two successive years of warm temperatures at juvenile – early adult period should substantially decrease the abundance of the large form of jumbo squid. It was shown to be the case in the last three years, when a strong El Niño event in 2015-2016 caused decrease in size of jumbo squid and corresponding decrease in its biomass in Peru in 2017-2018 and in Chile in 2018-2019.

44. The workshop noted that the correlation of expression of phenotype with temperature seemed similar to what was presented earlier (paper SC7-SQ03) without making any differentiation between age-groups, as done here. It was identified that differences may be expected due to the use of a different temperature index; the previous paper used the Peruvian Ocean Index which is using information very close to the coast, while this paper uses more oceanic sea surface temperature indices from El Niño regions 1+2 and 3 (tropical and subtropical eastern Pacific). It was also noted that environmental factors can affect all life stages of marine species, not just juveniles.

45. It was noted that sea surface temperature explained only 13% of the variance and that squid have low egg mortality due to protective gelatinous egg masses. Jumbo flying squid are pelagic spawners in the open ocean, which is a safer environment because egg masses, larvae and small juveniles are far away from the coast, with fewer predators, and until they are larger than 3 cm they also remain above the main thermocline and don't migrate vertically. The presenter also noted trade-offs between growth and maturation in varying environmental conditions because squid become mature earlier in warmer waters.

46. The workshop noted the importance of knowing whether genotype plays any part in determining the phenotype expressed, for stock assessment purposes, but the presenter noted that given the plasticity of genomic expression, it is unlikely that the genotype plays any role in determining phenotype.

47. The workshop discussed the possible impact of salinity on the phenotype of the squid, but it was noted that it was not expected that salinity would affect growth and phenotype given the lack of variation in salinity in the open ocean.

48. It was noted that because of the wide variation in animal size, any eventual squid stock assessment should use animal numbers rather than biomass, and be able to follow cohorts with varying growth parameters through time.

49. The workshop noted the importance of food availability for growth, particularly of paralarvae and juvenile squid, but also that squid are not as limited in available prey as most finfish species given that their physical characteristics allow them to eat a wider variety of prey sizes.

50. Dr Arkhipkin clarified that El Niño area 3 was assumed to be a spawning ground, and El Niño area 1+2 was assumed to be a feeding ground for juvenile squid. The purposes of these assumptions was to name the temperature covariates, and investigate their correlation with ages of squid.

3.3 Squid Assessment Data and Modelling Approaches

51. The Secretariat presented SC7-SQ01 "Jumbo flying squid datasets held by the Secretariat". This paper identifies and describes jumbo flying squid data sets held by the SPRFMO Secretariat. It also shows a comparison of the data sets held by the Secretariat versus the FAO data series and provides some starter questions intended to progress a specific task contained in the 2018 work plan being – "Reconstruct historical total catch records including non CNCPs and non-members."

52. It was requested that the tables of catch be made available on the SPRFMO website.

53. The Secretariat agreed to follow up with affected delegations offline to resolve outstanding issues.

54. Chile presented paper SC7-SQ08 on "Direct evaluation of jumbo squid in Chile". The paper presents some results of the FIPA project 2015-16 "Direct evaluation of jumbo squid (*Dosidicus gigas*) in the south-central zone of Chile, methodological proposal". A number of studies were completed that focused on jumbo flying squid behaviour and trophic dynamics, but a few focused on estimation of the size, distribution, and geographical structure of jumbo flying squid stocks.

55. First, a literature review was completed on direct evaluation of jumbo squid, for which four methods were preselected and analysed; marking-recapture, swept area, hydro-acoustic, and fishing with jigging / lights. Secondly, a workshop was held with international experts, where the four selected methods were presented and the need to have an adequate tool to evaluate the stock of jumbo squid was discussed. A consensus was reached to use multiple methods to evaluate the squid resource. Finally, an exploratory cruise was carried out to test the methods selected for the evaluation (swept area, acoustics, and jigging / lights). The mark-recapture method was not used because jumbo flying squid is considered to have an open population. The prospecting cruise was carried out between June 3th and 29th 2016, which indicated that all three methods could be used to evaluate the stock. However, the choice of the best method was not entirely clear, as methodologies require further adjustments to achieve better results. Therefore, results from the study should be interpreted with caution.

56. Some participants considered that the paper did not accurately reflect all of the benefits of possible methods, in particular for hydro-acoustic methods. The workshop agreed that using hydro-acoustics would require some critical assumptions, in particular about target strength, but noted that all stock assessment methods rely on critical assumptions. It was noted that acoustic methods can be done much quicker than indicated, and can provide an index and possibly estimate biomass where information on target strength and size frequency distribution is available.

57. The presenter agreed that every method has pros and cons dependent on the particular area and objectives you are aiming to achieve. The paper was focused on the Chilean area, not the whole SPRFMO area and was done because it could be used as a biomass estimate and support the setting of TACs in the Chilean area. It was considered that there is too much uncertainty in target strength estimates to use hydro-acoustics for that purpose at this point in time.

58. There was a general discussion that the particular area, fishery, and intended use need to be considered at length when determining approaches to monitoring and surveying squid stocks. Some examples where surveys of recruitment before the fishing season are completed (e.g. US East Coast and Argentina) were provided that used different methods, depending on their areas.

59. It was identified that it might be useful to consider exploring a way to combine/integrate multiple types of surveys across multiple Members given the size and complexity of the SPRFMO squid fishery.

60. Peru presented SC7-SQ09 on "Monitoring system for the jumbo flying squid fishery in Peru". The paper describes the methodology used by the Peruvian Marine Research Institute, IMARPE, for obtaining biological and fisheries data and information from the local fishery for jumbo flying squid *Dosidicus gigas* as well as from scientific research vessels operating in Peruvian waters. The monitoring system described provides a standardised sampling and data recording tool to support the generation of reliable and comparable information in support of scientific research and timely decision-making with regards to the assessment and management of jumbo flying squid stocks and fisheries in Peru. Guidelines are provided on the material and methods used and steps to be followed according to the type of sampling site, the type of fleet and the type of information and data to be collected, including examples of the various forms used for compiling it. The methodology described in the paper is being applied by IMARPE for the gathering and systematic recording of fishery statistics as well as information and data on biological and population aspects of the jumbo flying squid at the main landing sites, research laboratories and on board fishing and scientific research vessels. It has been produced and published in IMARPE's Boletin (as Bol. Inst. Mar Perú. 33(2): 222-252) in two languages, Spanish and English side by side, and is presented here to assist in the consideration and discussions by the SPRFMO Scientific Committee of possible monitoring and sampling methodologies of jumbo flying squid used or to be used in the area of application of the SPRFMO Convention area.

61. The workshop **recommended** that standardise protocols be developed and agreed to improve the quantity and quality of fishery data and biological sampling information to support monitoring of the jumbo flying squid fishery in the SPRFMO Convention Area.

3.4 SPRFMO Squid Assessment

62. China presented SC7-SQ07 titled "Using a size-structure model to assess the Jumbo flying squid in the equatorial waters" by Luoliang xu, Gang Li, Jiaqi Wang, Xinjun Chen, Yong Chen. A size-structured model was used to assess the jumbo flying squid in the equatorial waters. The estimated biomass and recruitments from base scenario and two sensitivity scenarios have shown similar monthly trends. The preliminary results have shown the model's potential to parameterize the special biological characteristics of jumbo flying squid.

63. The workshop requested clarification on the nature of the increase in natural mortality in 27-40 cm long squid. The presenter clarified that this was based on an assumption that squid die very quickly once they have spawned and that the mortality weighting factors for different sized squid are derived from a function which identifies a proportion of maturity stage four squid based on available data.

64. The workshop discussed the assumptions of the model, including the potential effects of cannibalistic behaviour and squid movements on the estimates of proportion spawning and estimates of natural mortality, noting that there is not enough information to support modelling these aspects in more detail. It was also noted that should the stock assessment model be finalised, an MSE could be completed to evaluate the effects on the outputs of the assumptions.

65. There was further discussion about the assumption that this is an independent stock, which is considered unlikely, but was essential for the development of the model, and there is insufficient data to confirm or deny the assumption completely. The presenter highlighted that they are proposing that this would eventually incorporate data across all Members and assess the whole stock.

66. The workshop requested clarification around the sampling of squid, noting that all of the samples were of small squid, which creates a risk that some of them were medium or large phenotypes that had been sampled before reaching maturity (and therefore were not the small phenotype as assumed). It was clarified that all samples were from mature squid, but that males and females were not separated in the analysis, which might confuse the model given the difference in maturity timing characteristics of the two sexes.

67. The maturity function by month in the model was queried, and the presenter clarified that it was estimated combining data from all months, and therefore the stock assessment assumes that maturation and spawning is similar throughout the year.

68. The workshop discussed whether any time intervals had been explored, noting that other similar assessments used weekly time intervals. It was noted that there was currently insufficient data to use a shorter time interval, but that increased data collection could allow for it.

69. The workshop also noted the need to consider the particular characteristics of the SPRFMO jumbo flying squid stock when considering the most appropriate monitoring approach, including the species biology, regular migration of squid, and cannibalistic behaviour exhibited by squid.

70. The workshop **noted** that the size-structured model describes the population dynamics of jumbo flying squid in equatorial waters, but the current model should be improved to better capture the biological characteristics of the species.

3.5 Squid Workplan

71. The Squid part of the current SC multiannual workplan was presented.

72. Some sections were updated and coordinating members identified. It was agreed that the workplan would be re-circulated after the meeting for further refinement during the main SC7 meeting.

3.6 Squid CMM Discussions

73. The workshop noted that document SC7-Obs02 “Draft CMM for Jumbo flying squid” had been provided by CALAMASUR as an information paper intended to stimulate discussion and assist the SC in developing its advice to the Commission.

74. In general, following earlier discussions, and as indicated in the SC Workplan, workshop participants were very supportive of progressing a CMM for the squid fishery and identified some key components that should be considered by the Scientific Committee. These included data collection and submission requirements, and adopting precautionary management measures. However, there was no agreement on particular management measures that would be most appropriate and acceptable in a CMM at this time.

75. There was vigorous discussion about possible management measures, primarily focused on the level of information required to support implementation of either management approach.

76. For implementation of an effort limit, discussions focused on how to ensure that it is fishing power that would be managed, and the information required on current levels and types of effort to support setting such a limit. There were also concerns raised that the limit should not allow for changes in vessels or tonnage that would result in an increase in fishing power beyond an established vessel limit. It was proposed that dual effort limits could be applied, a limit on vessel numbers complemented by a limit on tonnage. It was noted that in the Falkland Islands (Malvinas), they have a defined effort 'unit' which is intended to ensure that effort management is managing fishing power and not just vessel numbers. Some Members noted that their domestic regulations require specific approval to increase tonnage or fishing capacity, but this does not apply to all Members and therefore needs to be considered when deciding on what type of effort limit could be set. The Secretariat clarified that information on registered vessels is available on the SPRFMO website to support any analyses of current fishing effort, and that fishing for jumbo flying squid in the Convention Area is almost entirely done with squid jigging, which might simplify this aspect.

77. Implementation of temporal and spatial restriction to protect spawning and nursery areas was proposed. A depletion model to estimate percentage of biomass escapement at the end of its fishing season in its EEZ has been explored in Chile, but there is concern that squid that survive (and 'escape') could be fished later when they migrate to spawning grounds (north of Chile and south of Peru).

78. In regard to possible implementation of temporal or spatial restrictions to protect spawning squid/ensure sufficient escapement, discussions focused on how much information is available to identify the timing and area of spawning, with a number of Members considering there to be insufficient information to support implementing restrictions at this time. Other Members considered that there was sufficient information to implement some temporal restrictions on fishing, especially temporal closure during the main spawning peak (September-November) as suggested by Dr Arkhipkin.

79. In general, there was not agreement on progressing a CMM at this time. However, in order to enable the Scientific Committee to have a robust discussion and identify key gaps, the views of each Member were recorded and are provided below.

80. China was supportive of freezing fishing effort through a limit on vessel numbers, and support the protection of spawning biomass in principle, but consider that more information is required to develop specific regulations.

81. Peru was supportive of some kind of freezing of fishing effort in the Convention area making the point that it should not just consider the number of vessels, but fishing effort in a way that explicitly incorporates fishing power. It suggested that temporary area closures during the peak of the spawning season could also be considered.

82. Chile considered more information and analysis is required to implement a limit on fishing effort, and was very supportive of implementing temporal restrictions on fishing to protect spawning squid. Chile considered that a workshop or workshops to better understand fishing effort would better support implementation of management measures, and for that reason considered that more time is required to develop and agree a CMM for squid.

83. Ecuador agreed with the proposition of Chile, considering that there is not enough information to limit fishing effort at this time.

84. The EU noted the potential for spawning timing and location to vary across years and noted that this might make it difficult to allocate a single closed area or season to protect spawning.

85. Korea wanted to take more time to consider the proposals before developing a position.

86. Under the principle that there would be regular review in following years, Peru supported freezing fishing effort, some kind of temporary restriction on fishing during spawning season (identified as between September and October, but with uncertainty), and also a possible mechanism to close the fishery if CPUE dropped below a certain point. Peru also reiterated the importance of including elements regarding data and information collection in any CMM to codify the commitment to good, relevant, and timely information being provided to the Secretariat.

87. Chinese Taipei agreed with the views of the Chinese delegation and considered that more information is required to implement temporary restrictions on fishing to protect spawning.

88. CALAMASUR noted the lack of agreement and suggested that the workshop recommends that the Scientific Committee should identify gaps that need further research to support temporal restrictions, noted that effort limits need to be based on operational effort (not registered effort), and highlighted the need to discuss at-sea sampling needs to support stock assessments and the associated observer coverage level requirements.

89. It was noted that there was no agreement on common elements for an appropriate CMM to be developed at this stage, but the workshop supported a future CMM including data gathering and reporting, catch limits, fishing efforts limits and temporal and spatial closure for the jumbo flying squid fishery.

90. The squid working group acknowledged and recommended that more information and studies would support development of more comprehensive management measures.

3.7 Observer Coverage

91. Korea presented SC7-SQ05 on "Observer report on squid jigging fishery in the SPRFMO Convention Area".

92. Information on the biology of the target species, *Dosidicus gigas* (jumbo flying squid) and components of the ecosystem which may be impacted by fishing were collected through observers on squid jigging vessels in the SPRFMO Area. Six species including the target were observed.

93. A total of 1,777 jumbo flying squid were measured for biological data and the overall mode of mantle length frequency was similar between both sexes. The dominant stage of maturity observed for both male and female jumbo flying squid was stage 3 (Mature). Stomach contents of sampled jumbo flying squid consisted primarily of cephalopods, fish, macrura, and seaweeds.

94. Squid jig fishing is mainly operated at night and doesn't discharge offal or other fish waste during operations. Accordingly, no entanglement of seabirds was observed during fishing operations. Using the biological samples collected by observers, age determination, prey composition, and genetic analysis is possible in the future. Korea is planning to strengthen its efforts to dispatch observers on squid jigging vessels.

95. There were questions about the guidance for observers to differentiate between Stage 1 and Stage 2 when staging gonads, and whether the bycatch of octopus was in pelagic waters or on or near the bottom. The presenter clarified that the primary difference in staging was size of gonads, but that there was a guide provided, and that the jigs rarely touch the bottom, so the octopus was likely to have come from pelagic waters.

96. Dr Arkhipkin queried the large squid seen in the south from September to October, and how they were caught given that it seems to be generally known that jigging machines do not catch large squid, but he noted that if the catch of large squid is accurate, the timing of larger squid coming into the area is consistent with the Chilean view of the squid life cycle. The presenter explained that they use variable squid jigging machines to catch jumbo flying squid, and that there were some adjustments by experienced captains made to enable the catch of large squid.

97. China presented SC7-SQ06 titled "Preliminary Simulation Study of the Observer Coverage Rate Estimation for the squid jigging fishery based on 2018 China Observer Program". A total of more than 25,000 samples were collected from the observer programme from 2018 to 2019, most from an on-board observer monitoring programme. Increased observer monitoring could provide information with higher quality. The optimal coverage rate could not be determined with the current dataset. However, it was found that an observer working on the same vessel for the whole fishing season may not be necessary.

98. The presenter suggested that increasing observer numbers, improving the sampling methods and sharing data from fishing entities to design a science-based observer programme would support future work and stock assessment of squid.

99. The workshop noted the limitations on the data that currently supports the simulation, in particular the limited range of squid sizes in the samples. They expressed an expectation that if there was a wider size range, or more mixed sizes in the samples, that more observer coverage would be estimated as necessary. The presenter clarified that there were at least two phenotypes in the data, although acknowledged that they weren't generally present at the same time. The presenter also emphasised that the basic assumption of the simulation study was that the observer data were representative of the entire population and having more observers and observer data would improve the data's representativeness.

100. The presenter clarified that large squid are caught by hand jigging in particular areas where it is known that large squid are more common.

101. It was noted that more observer data are needed to estimate the difference in size composition of catch among fishing vessels and the sampling methods could be improved.

102. The workshop **recommended** that more observers would be needed to improve the data collection.

3.8 Connectivity

103. Peru presented SC7-SQ10 on "Protocol for the collection of jumbo flying squid *Dosidicus gigas* muscle tissue for molecular analysis used by the Instituto del Mar del Peru (IMARPE)". Several molecular techniques from the traditional to the recent NGS (Next Generation Sequencing) can be used in population genetic analysis for the evaluation of different levels of variability throughout a species genome. The application of a particular molecular technique depends not only on the resolution of the genetic variability but also on the sampling design, including factors such as periodicity, spatial distribution, quality and type of tissue and DNA available, DNA integrity, etc. A critical aspect to consider, is the tissue collection and preservation to guarantee the quality of DNA and avoid degradation over time, allowing its use for long field studies. Therefore, the use of lab protocols is important to ensure that different methods are performed with safe procedures.

104. The paper provided a detailed description of the methodology that IMARPE is considering for biological sampling of jumbo flying squid, specifically for population genetic analysis. Details were given for catch, preparation of the work area, sample collection and its conservation, along with a scheme of collection sites in representative areas of the Peruvian jurisdictional waters. Finally, they noted the importance of using a standardised protocol for the evaluation of the jumbo flying squid in order to compare species distribution patterns.

105. The squid working group **agreed** to coordinate standardised approaches for genetic sampling and sharing of samples/specimens.

106. Peru presented SC7-SQ11 on "RAD sequencing technology for the evaluation of the population genome variability of the jumbo flying squid *Dosidicus gigas* in Peruvian waters." The jumbo flying squid *Dosidicus gigas* exhibits a complex structure along its distribution in the Pacific Ocean. Different groups of individuals showing contrasting size, growth rate and sexual maturation time have been reported, and great interest exists in knowing the spatial and temporal distribution of their genetic variability related to these phenotypic groups. Although genetic studies have been carried out on this species, only a few loci have been successfully evaluated. Even more, the difficulty of generating genomic information in non-model species, like the jumbo flying squid, with large and complex genomes is well known; so several markers should be considered to strengthen population structure inferences. Increasingly population genetic studies are using RAD sequencing for identifying single nucleotide polymorphisms (SNPs) in whole genomes, because it is considered a more sensitive tool that could elucidate population patterns in organisms with dispersal potential and high connectivity among distant populations. In this sense, IMARPE has elaborated an instructive guide for tissue sampling and proposed the use of ddRAD-seq method to perform population genetic analysis of *D. gigas* across its latitudinal and longitudinal distribution in the Peruvian jurisdictional waters.

107. The working group asked about the potential for this technique to allow differentiation between stocks on a timeframe relevant for management of the squid fishery. The presenter clarified that this method is similar to that being done by China (see SC7-SQ12) in that both are high-throughput techniques for the evaluation of SNPs in genomes, and that the interpretation of results, including relevant timeframes, is dependent on the marker being used. Looking across a number of genetic areas can allow you to look at relevant timeframes. The presenter also noted the importance of collecting the associated biological information from squid being sampled for genetic analysis to help correlate genetic and phenotypic characteristics.

108. The Chair also asked if there were any results available that might show genetic difference between large and small squid. Peru responded that results are expected to be available at the end of 2019 or early 2020.

109. China presented SC7-SQ12 titled "Genetic diversity and population structure of *Dosidicus gigas* in the Southeast Pacific Ocean based on genome-wide SNPs by genotyping-by-sequencing" by Congcong Wang, Gang Li, Bilin Liu, Xingxing Hu, Hao Xu. Based on the simplified genome sequencing technique of Genotyping-by-sequencing (GBS), the genetic structure and diversity of large and small phenotypes of *D. gigas* in the southeast Pacific Ocean were studied in this paper by using Single Nucleotide Polymorphisms (SNPs) markers. The result showed that the GBS technique was suitable for evaluating the genetic diversity of cephalopod with high diffusion potential. In terms of genetic diversity, the two phenotypes have shown a decline in genetic diversity and loss of heterozygosity. According to population differentiation, the two phenotypes did not differentiate significantly and did not form geographical isolation, so they could be managed as a whole.

110. The group noted that in order to obtain a more accurate population genetic structure of jumbo flying squid, we need to expand the sampling area and increase the number of samples in the next step. In the study of the population's genetic structure of *D. gigas*, it's more appropriate to use the high resolution molecular markers, such as SNPs, and apply the same technology to obtain and analyse SNPs, for example the GBS or RAD-seq. The presenter suggested sharing sequencing data among members.

111. Considering the difference between sample numbers of small (n=30) and large (n=8) squid used in their study, the workshop queried whether a larger sample size, particularly of the big squid, would give more ability to differentiate between large size-group and small size-group squid, and if so, what sample size would be considered to be enough for that. The presenter agreed that more samples, and equal sample sizes from the two (or three) group-sizes would improve the confidence in the results.

112. The presenter clarified that all samples were from mature squid to be certain that they were of the relevant phenotype since non-mature small squid might grow to be large squid by the time they mature. The workshop also queried why there were none of the medium sized squid phenotype included in the analysis. The presenter clarified that this was due to limited samples, and noted that the analysis could include all three phenotypes if samples were available in future.

113. It was suggested that it would be useful to identify and agree standardised protocols for sample collection and storage, and agree on sample sizes that will support statistically robust answers.

114. The workshop noted that this work suggests a single genetic metapopulation for jumbo flying squid in the Southern Pacific Ocean.

115. The workshop discussed the level of confidence in the result from the analysis, noting that it looked only at a small number of loci, and genetic differences could be potentially in other loci not being analysed in this work. It was identified that squid have highly variable genetics, and that there is a difference between genetic variability and differentiations between stocks of the same species. However, the presenter clarified that they did not expect a different result if they looked across a higher number of loci. It was noted that having two Members using similar, but slightly different techniques at the same time will provide more confidence in the outputs, and that the Peruvian study is expected to report back at the end of 2019 or early 2020.

116. Dr Arkhipkin clarified the importance of separating genetic variability and diversity from the separation of genetic populations. If the results show that genetic diversity is large, but all intermixed, we are dealing with a single, highly diverse, population, but if the results show statistically that the groups are separated, it means that they are genetically distinct and therefore do not represent a wider metapopulation. The workshop noted that the purpose here is not to identify a separate species, but it is to look at possible population subunits that might be of interest for stock assessment and fisheries management purposes, so the genetic differentiation may not need to be as clear.

117. It was noted that the samples used in the study were from different areas, all of the small squid were from the equatorial region, and large squid were from the Convention Area further south. The workshop asked if there were any plans to cross-validate, noting that it is likely not possible to find large squid in the equatorial region and that although it would be ideal to have samples from all three phenotypes in the same area, it is likely not possible.

118. The workshop noted that the results from the study by China would likely have been considered sufficient to inform management in other regimes (e.g. Patagonian shelf), so it should not be ignored, but agreed that more work is required.

119. The workshop suggested that the two genetic analysis approaches could be combined and/or used simultaneously to have more confidence in the results.

120. The workshop noted an initial need to wait for the results of the Peruvian study to be able to identify if there are any particular benefits to follow one method over the other. They also noted that in genetics, a sample size of 20-30 is generally considered to provide statistically robust results, and once you have some results, sample sizes can be reduced. It was identified that it would also be important to analyse the genetic differences across characteristics other than just phenotype to identify possible differences in groups other than sizes, related to sex, maturity stage, etc.

121. It was also noted that last year there were no genetics experts involved in the discussions and felt that their recommendations this year with regards to sampling and methodology should be incorporated into this year's advice on sampling and analysis protocols.

122. The workshop agreed that all Members that fish for squid have the capability to collect genetic samples, and recommended that the genetic analysis programme be coordinated by Peru and China working with other members using a standardised sampling protocol.

123. It was noted that there are other stocks of jumbo flying squid in other parts of the eastern Pacific such as Mexico and United States where there may be similar work going on. It might be beneficial to get in touch with them to get some samples for comparison with the South Pacific stocks to help identify where genetic changes are most likely to be. It was identified that those stocks are not within the Convention Area, and that efforts should focus on the stocks in the Convention Area, but noted that there may be some scientific benefit to engaging with genetics experts in those areas who are working on *D. gigas* and suggested that those experts be invited to engage on this programme.

124. The squid workshop **noted** that there are other stocks of jumbo flying squid beyond the South Pacific, and recommended getting some samples for comparison to help support the investigation and validation of stock structure.

125. The squid workshop **agreed** to use standardised approaches for genetic sequencing, and sharing of genetic markers.

3.9 Other Squid Topics

126. Dr Arkhipkin presented a report on usage of statolith chemical signatures to confirm ontogenetic migrations of the squid *Doryteuthis gahi* around the Falkland Islands (Malvinas) in the Southwest Atlantic. The population consists of two temporally distinct spawning cohorts, inferred to have markedly different patterns of migration and timings of ontogenetic events. Ontogenetic migrations of each cohort were confirmed by analysis of the chemical composition of statoliths collected from both cohorts in two consecutive years. Trace element concentrations were quantified using laser ablation inductively coupled plasma mass spectrometry (LA ICP-MS), to determine temporal and cohort-specific variation. Individual ablation craters, ablated in a transect from the nucleus to the rostrum edge, were aged to produce high-resolution elemental chronologies. Generalised additive mixed models (GAMM) indicated that cohort and life history stage had a significant effect on Sr:Ca and Ba:Ca concentration ratios. Sr:Ca and Ba:Ca ratios were both negatively correlated with near-bottom water temperature, with Ba:Ca also potentially correlated to depth. Statolith elemental fingerprints have useful applications as natural tags, discriminating between spawning cohorts. Dr Arkhipkin suggested drafting a proposal on usage of microchemistry analysis to identify intrapopulation structure of jumbo squid in the Southeast Pacific.

127. He then presented on management of the Patagonian longfin squid *Doryteuthis gahi* in the Falkland Islands (Malvinas). The fishery management of *D. gahi* is based on the strict control of fishing effort. The choice of effort limitation as the primary management tool was made taking into account an annual life cycle and high variability in abundance from year to year. With a very weak stock-recruitment relationship the management target has been to maintain spawner escapement biomass above a level that appreciably decreases the probability of poor recruitment (currently 10,000 t for each cohort). In-season monitoring remains important to allow the possibility of reducing effort in years where a low recruitment implies that a constant harvest rate will not be sufficiently conservative. Several management measures are currently in force to conserve the squid stocks. Temporal restrictions (in the form of the early closure of the fishery season) may be used in cases when in-season estimations of stock size show that the stock is approaching a minimum escapement level. Spatial restrictions (in the form of areas temporally or permanently closed for fishing) may be used to prevent the fishing of dense schools of small juvenile squid during their offshore feeding migrations. The locations and timings of closed areas may vary interannually depending on environmental conditions, which determine the distribution of young squid. Reductions in fishing effort could be used in case of predicted poor recruitment of *D. gahi* for a given fishing season, though predictive ability is limited at present. If assessments indicate that minimum spawning stock biomass targets were not met then effort may be reduced in following seasons to take account both of the fact that recruitment may have been reduced and that fleet performance may have been underestimated. The current management practice, in the form of fishing effort regulation by restrictions in number of licenses, together with in-season spatial and temporal restrictions of the fishery is flexible enough to conserve the stocks of short-lived *D. gahi* around the Falkland Islands (Malvinas) at a sustainable level.

128. It was noted that the CMMs in the Falklands Islands (Malvinas) serve a variety of purposes, including allowing for spawning escapement. The extent that this sort of approach requires a stock assessment before it can be implemented was discussed for jumbo flying squid. Could a CMM based on, for example temporal or spatial patterns require having good knowledge of where and when spawning occurs. The group noted that a stock assessment would likely be required. Also, knowledge on the life cycle and demography of squid would be essential to developing defensible temporal and spatial CMMs.

129. It was noted that if chemical analysis of statoliths was going to be proposed for *D. gigas*, it would be good to complement it with genetic studies. Dr Arkhipkin agreed that simultaneous sampling of statoliths for chemical analysis and genetic samples from the same individual squid would be advantageous.

130. The workshop noted an alternative perspective on the protection of spawning squid given their biological characteristics. If they die shortly after spawning and they are not fished, this may result in lost catch that is just going to die and not be available to the fishery. Other workshop participants agreed, and noted that the overall objective is to ensure that there is sufficient escapement of squid, i.e., ensuring that enough females make it to spawn which could be achieved by temporarily protecting spawning areas, or by limiting catch or stopping fishing altogether if a cohort is reduced below a certain level (possibly measured by CPUE).

131. The workshop suggested that statolith samples should be collected whenever genetic samples are being collected to enable future chemical analyses.

132. The squid working group **recommended** that alternative microchemistry studies of statoliths of jumbo flying squid be done to verify their population structure.

4. Recommendations to SC7

133. The squid working group made the following recommendations to SC7:

1) Notes that important steps forward have been made with respect to stock assessment and genetic studies for jumbo flying squid but there is still much work to do including understanding the phenotype dynamics, improving the quantity and quality of fishery data and biological sample collection.
2) Notes that the size-structured model describes the population dynamics of jumbo flying squid in equatorial waters, but the current model should be improved to better capture the biological characteristics of the species.
3) Agree to develop data templates to support stock assessment and monitor the fishery of jumbo flying squid.
4) Agree to coordinate standardised approaches for genetic sampling.
5) Agree to coordinate the use of standardised approaches for genetic analysis based on high throughput techniques, sharing of the sequencing data.
6) Agree to do alternative studies on fine population structure of jumbo flying squid using microchemistry of their statoliths.
7) Agreed to make a workshop on the study of fishing effort dynamics and fishing power estimates.
8) Note that there are other stocks of jumbo flying squid in other parts of the north-eastern Pacific, and recommends getting some samples for comparison with the South Pacific stocks to help support the investigation and validation of stock structure by using samples taken from known, separate stocks.
9) Notes that in order to address Recommendations 108 (a) and 178 (c) by the Review Panel, the workshop participants supported a future CMM including data gathering and reporting for the jumbo flying squid fishery with several possible management approaches including catch limits, fishing efforts limits and temporal and spatial closures being discussed.
10) Notes that there was no agreement on common elements for an appropriate CMM to be developed at this stage and an acknowledgement that more information and studies would support development of more comprehensive management measures (on hold).

5. Adoption of Report and Meeting Closure

134. Various draft versions of the report were circulated during the main SC7 meeting and participants were asked to review the draft with a view to adopting it during the thirdday of the main SC meeting.

135. The report was adopted at 9:45 am on 11/10/2019.

SPRFMO SCW8-Report

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SPRFMO SCW8-Report

Annex 2. SCW8 Agenda

1. Basic biology
   - 1.1 Age, growth and maturity
   - 1.2 Spawning, reproduction and migration mode
   - 1.3 Foraging behavior and diet composition

2. Stock assessment, data and modelling approach
   - 2.1 Catch and CPUE data
   - 2.2 Biological data sampling and observer coverage simulation study
   - 2.3 Acoustic surveys data and biomass estimation
   - 2.4 Stock assessment model development and testing

3. Squid connectivity
   - 3.1 Standardised genetic sequencing method and data analysis
   - 3.2 Stock structure and connectivity

4. Squid related CMM
   - 4.1 Precautionary measures on Protecting Area for spawners
   - 4.2 Other potential measures

5. Other matters

SPRFMO SCW8-Report

Annex 3. Workshop Documents

SC7-SQ01	Squid Datasets held by the Secretariat
SC7-SQ02	Distribution and fishing of jumbo squid off the Chilean coast in the 2019 season
SC7-SQ03	Changes in predominance of phenotypic groups of Jumbo flying squid in Peruvian waters
SC7-SQ04	Protocol for biological and biometric sampling of Jumbo Flying Squid in Peru
SC7-SQ05	Korean Observer report on squid jigging fishery in the SPRFMO Area
SC7-SQ06	Simulation study estimating observer coverage rate based on the 2018 China program
SC7-SQ07	A size-structure model to assess the Jumbo flying squid in the equatorial waters
SC7-SQ08	Direct evaluation of Jumbo squid in Chile
SC7-SQ09	Monitoring system for the Jumbo flying squid fishery in Peru
SC7-SQ10	IMARPE protocol for collecting jumbo flying squid muscle tissue for molecular analysis
SC7-SQ11	RAD sequencing technology for the evaluation of the Jumbo flying squid in Peru
SC7-SQ12	Genetic diversity and population structure of jumbo flying squid in the Southeast Pacific
SC7-SQ13	Jumbo flying squid distribution in Peruvian national waters during 2018-2019
SC7-SQ14	Environmental variability and abundance, availability, size and condition of Squid in Chile