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An assessment of NAFO roughhead grenadier Subarea 2 and 3 stock.

by

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**ABSTRACT**

The aim of this paper is to present the status of NAFO roughhead grenadier Subarea 2 and 3 stock. A qualitative assessment based on survey and fishery information was carried out. There are not available surveys indices covering the total distribution, in depth and area, of this stock. Biomass indices from the surveys with depth coverage till 1400 meters are considered as the best survey information available to monitor trends in resource status because they cover the depth distribution of roughhead grenadier fairly well.

Surveys biomass indices present a general increasing trend in the period 1995-2008. Since then, all available indices show a general downward trend except the Canadian Fall (2J+3K) index. This index presents an increasing trend. With regard to fishing mortality, it can be observed a clear decrease trend from 1995 to 2007 and since then are more or less stable at very low level. The estimated recruitment indices in size and age do not provide much information. It can be observed an increase in the abundance of small sizes (less than 10 cm) after 2010 until 2018..

**INTRODUCTION**

Roughhead grenadier (*Macrourus berglax* Lacépède, 1802) is an abundant widespread fish species in the North Atlantic, usually found both on the shelf and on the continental slope (Scott and Scott, 1988; Savvatimsky, 1994). It is predominant at depths ranging from 800 to 1,500 m (Murua and De Cárdenas, 2005), although they may inhabit depths between 200 and 2,000 m (Snelgrove and Haedrich, 1985; Murua and De Cárdenas, 2005). It has, however, been rarely found in depths down to 2,700 m (Wheeler, 1969). This species is commonly found in temperatures ranging from about -0.5 to 5.4 °C (Atkinson and Power, MS 1987).

The fishery for Roughhead grenadier is unregulated and it is taken as by catch in the Greenland halibut (*Reinhardtius hippoglossoides*) fishery (Gonzalez-Costas, 2012), mainly in NRA Divisions 3LMN. Most Roughhead grenadier catches are taken by trawl and the only management regulation applicable to Roughhead grenadier in the NRA is a general groundfish regulation requiring the use of a minimum 130 mm mesh size.



The knowledge on the biology and population dynamics of Macrouridae is sparse (Gordon, 1979; Middleton & Musick, 1986; Atkinson, 1995; D'Onghia et al., 2000). In particular, little has been published on the biology, growth and reproduction of Roughhead grenadier on both sides of the North Atlantic. Moreover, the age structure and growth of the Roughhead grenadier, based on otolith readings of specimens captured in the North-West Atlantic, were estimated by Murua and González (2007) and have been updated with the data until 2018 in this document. Garabana et al. (2016) analyze the spatial and temporal variability of size and age at maturity of roughhead grenadier females in NAFO divisions 3LMN based on microscopic maturity staging and individual age readings.

The stock structure of this species in the North Atlantic remains unclear because there is little information on the number of different populations that may exist and their relationship. In the Northwest Atlantic Fisheries Organization (NAFO) area, Roughhead grenadier is distributed throughout Subareas 0 to 3. However, for assessment purposes, NAFO Scientific Council considers the population of Subareas 2 and 3 as a single stock (NAFO, 2005). Although the knowledge available on the biology of this deepwater species is not extensive, over the last few years, more biological information as well as research survey indices have been analysed (Murua et al. (2005); Garabana et al. (2016) and Gonzalez-Costas (2016). The aim of this paper is to present the status of this stock using all the available information.

## Data

### Catches

In 1998 Power and Maddock Parsons revised the Roughhead grenadier catch statistics since 1987 for assessment purpose. Before 1987 there is not roughhead grenadier catch information available in the NAFO STATLANT data base. This could not mean that there should not have catches of this species before 1987. The reason for this doubt it is that before 1987 roundnose grenadier was the only name that appeared in the STATLANT reporting forms. Table 1 and Figure 1 show the 1987-2018 NAFO Subarea 2 and 3 catches for this species. Since 1987, most of the Roughhead grenadier catches were taken as by-catch in the Greenland halibut fishery in Div. 3LMN by Spain, Portugal and Russia fleets. Catches increased sharply from 1989 (333 tons) to 1992 (6725 tons); since then until 1997 total catches have been around 4000 t. In 1998 and 1999 catches increased and were near the level of 7000 tons. In the period 2001–2004, catches decreased to 3000–4000 tons and to 1000 tons in 2007. In the period 2007-2012, annual catches have been around 1000 tonnes and since then catches have been about or less than 500 tonnes.

### Catches Length Distributions

Roughhead length frequencies from the Spanish, Portuguese and Russian trawl in Div. 3LMNO are available from the Spanish Research Report (Gonzalez-Costas *et al* 2017, 2018 and 2019), Portuguese Research Report (Vargas *et al.* 2017, 2018 and 2019) and Russian Research Report (Fomin K. and M.Pochtar 2017, 2018 and 2019). Table 2 presents the availability of the length distribution in the series. The Spanish and Portuguese lengths frequencies are measured as pre anal fin length (AFL), while the Russian ones as total lengths. The roughhead length compositions from the Russian catches have been converted to AFL using the total length / AFL relationship presented by Murua and Motos (1997) until 2015. This transformation has not been carried out for the period 2016-2018 due to the low sampling level and small Russia catches. Due to the growth differences between sex, length and age data have been analysed by sex. Figure 2 shows the length distribution by year and country for Spain and Portugal in the period 2016-2018. The Spanish length distributions are different from the Portuguese ones. The Portuguese fleet catch individuals smaller than the Spanish in 2016 and 2017 and bigger in 2018. The 2016-2017 pattern is similar to the observed in the period 2010-2015. The size distribution of Portugal in 2018 is quite different from that of the previous years capturing individuals of much larger sizes. Total catches length distributions for the stock were estimated raised the join Spanish and Portuguese catches length distribution to the total catches. Table 3 presents the total catches length distribution and Figure 3 shows the 2016-2018 length distribution of the roughhead grenadier Subarea 2+3 stock. In the years 2016 and 2017 the mode of the catches length distribution is 10 cm. This is less than that observed in previous years that were around 12 cm. In the year 2018 the catches are composed of very large

specimens with a mode around 14-16 cm. Figure 4 presents the sex ratio by length of the catches length distributions for 2016-2018. The proportion of males in the catches after 18 cm decreases progressively as length increases and it is very difficult found males more than 28 cm. This patten is the same founded in previously studies (Murua and Gonzalez, 2007 and Gonzalez-Costas, 2016).

### Catch-at-Age

Ageing was based on otoliths from specimens caught by Spanish commercial fleet and UE scientific surveys in NAFO Divisions 3LMN. Table 2 presents the data available to create the catch-at-age matrix. The total catch-at-age numbers and the associated mean weights and mean length by age presented by González-Costas (2016) have been updated with the 2016-2018 information (Table 4 and Figure 3). The 2016-2018 Age length keys (ALKs) were presented in the Spanish Research Reports (Gonzalez-Costas et al 2017, 2018 and 2019). In the period 2016-2017, most of annual catches are composed between ages 3 and 5, with a mode at age 4. These age distributions are lower than that observed in 2018 where the mode was between 5 and 6 years. The age distribution of 2018 was similar to those of the 2010-2015 years and a little smaller than those of the 2008-2009 period. These differences in the distributions of total sizes are influenced by the relative weights of the size/age distributions of the different countries, mostly from Spain and Portugal.

### Research Survey Data

Biomass indices for the roughhead grenadier Subareas 2 and 3 stock are available from various research surveys, with different depth and area coverage (Table 5). None of them cover the total area and depth distribution of this stock.

**Canadian deepwater survey:** Canada conducted deepwater bottom trawl surveys (750 – 1500 m.) in 1991, 1994 and in 1995 in Divisions 3 KLMN. The results of those surveys were reported by Bowering *et al.* (1995), and are presented in Table 6. Most part of the biomass was taken in Div. 3L and 3M at depth more than 700 m., which confirms that the stock in those Divisions is distributed beyond the depths covered by the spring surveys in those Divisions.

**Canadian fall survey:** Stratified random bottom trawl surveys have been conducted in Div. 2GHJ and 3KL in fall since 1978, usually in October-November. Since 1990 the survey also covered Div. 3MNO. Until 1995 an Engel trawl was used, changed since then to a Campelen 1800 gear. At the beginning of the surveys depth coverage was up to 1000 m in Div. 2GHJ and 3K and to 730 m in Div. 3LNO, it was extended to 1463 m after 1995. A description of those surveys is in McCallum and Walsh (1996) and Power and Parsons (1998). Operational difficulties in some years lead to incomplete coverage (depth and surface) of the survey (Brodie 2005; Healey and Dwyer, 2005, Healy 2009, Healy *et al* 2012 and Rideout R.M., D.W. Ings, 2019). The estimates from 1995 onwards are not directly comparable with the previous time series due to the change in the survey gear. Taking into account the incomplete coverage of some strata in divisions 2GH and 3LMNO only the index of divisions 2J and 3K from both series (Engel and Campelen) are comparable. It was determined that the coverage deficiencies within Divs. 2J3K were such that the 2008 index from Divs. 2J3K could not be considered comparable to that of previous years (Healey and Mahé, 2009). The percentage of the total index (MWPT) in the strata non surveyed in 2018 represent between 40% and 70% of the biomass index in previous years (Figure 5). The trend of the index with all strata and only with the strata surveyed in 2018 are similar although the levels are quite different (Figure 6). Therefore, it has been decided not use the 2018 Canadian survey information in this assessment.

The roughhead biomass index (DIV. 2J3K MWPT) from this survey since 1978 are presented in Table 6 and Figure 7. This series presents small differences with the one used in the 2016 assessment. These differences are due to the fact that the one used up to 2016 lacked information from two strata. The Engel series (1978-1994) present a clear decreasing trend since 1978 till 1994. The Campelen series shows an opposite trend, the index shows a general upward trend in the period in the period 1995-2017.

Rideout R.M., D.W. Ings, 2019 presents the Canadian fall survey length distributions (Figure 8).

**Canadian spring survey:** Stratified random bottom trawl surveys have been conducted in Div. 3L, 3N and 3O in spring since 1978. A description of those surveys is found in McCallum and Walsh (1996). Until 1996 an Engel trawl was used, changed to a Campelen 1800 since then. The depth range of the surveys is up to 731 metres. Roughhead grenadier information is available from this survey since 1991. But again in this case a direct comparison of the biomass levels through the whole time series is not possible due to the change in the survey gear in 1995. Operational difficulties in 2006 and 2015 resulted in incomplete coverage of the survey in Div. NO and the estimates for these years are not directly comparable with the time series (Rideout, 2016). Table 6 present the estimated Roughhead grenadier biomass index (MWPT) from this survey and Figure 9 shows this biomass index since 1996 till 2018. From 1996 to 2004, the biomass level was more or less stable. In 2005 and 2007, it had a big increase and from 2008 to 2018 it was more or less stable at similar level than the period 1996-2004. The index in the last three years rises and falls without a clear trend. Biomass estimates from the spring survey series are considerably lower than the ones obtained in the autumn series, as the spring surveys cover only the southern divisions and the shallower depths, where according to other information this species is less abundant.

Rideout R.M., D.W. Ings (2019) presented the spatial pattern of catches in the Canadian autumn and spring surveys for the period 1998-2015 in order to summarize the distribution of NAFO stocks including roughhead grenadier in SA2+3. Although the depth coverage of the surveys are different, it can be observed that the largest catches for both surveys are made throughout the deeper part of the slope every year.

**Flemish Cap (EU Spain and Portugal) 3M survey:** EU- Spain and Portugal conduct a stratified bottom trawl survey in Div. 3M since 1988, up to depths of 730. The survey procedure is described in Vázquez *et al.* (2013). Since 1991, the survey was made with the R/V Cornide de Saavedra. In 2003 this vessel was replaced by the R/V Vizconde de Eza. The former series of Cornide de Saavedra was transformed to the new R/V Vizconde de Eza units following the method presented by Gonzalez Troncoso and Casas (2005). In 2004 the depth coverage of this survey has been extended to 1463 m. The Roughhead grenadier biomass indices from this survey series have been presented by Gonzalez-Troncoso *et al.* (2019) and are shown in Table 6 and Figure 10 of this document. The 730 m. biomass index presents a peak in 1993. From then until 2002, the biomass index was more or less stable at values in between 1 and 2 kg per tow. In the period 2002-2008 the biomass index increased its level but it was quite variable between years. Between 2009 and 2011 the index decreased and since then it is quite stable at low levels. The 1400 indices show a clear decreased trend since the beginning of the series (2004) until 2013 and since then it is quite stable at low levels. Figure 11 presents the length and age distributions of the EU Flemish Cap survey from 2004 to 2018 until 1400 meters depth. The transformations of the lengths in ages were made applying the EU Flemish Cap survey ALKs to the length distribution indices. Although the tracking of cohorts in time is not clear, it can be observed a strong 2001 year class. Since then there are not good recruitment signals in this index.

**EU-Spanish 3NO Survey:** EU-Spain conduct a stratified random spring bottom trawl survey in the NAFO Regulatory Area Division 3NO since 1995. In 2001 the C/V Playa de Menduñña with a net trawl type Pedreira was replaced by the R/V Vizconde de Eza, using a trawl net type Campelen. The transformed entire series of mean catches, biomass and length distributions for Roughhead grenadier were presented by Gonzalez-Troncoso *et al.* (2019) since 1997, year in which the survey was extended to the 1400 meters depth. The roughhead grenadier biomass index from this survey series is presented in Table 6 and Figure 12 From 1997 to 2002 the biomass index of this survey was stable. Since then it has increased and in the period 2004-2006 reached the maximum level. In 2007 decreased and since then until 2012 was more or less stable at similar 2003 level. In the period 2012-2018, the index level decreases a bit being quite variable between years. The length and age distributions of the survey series are showed in Figure 13. The transformations of the lengths in ages were made applying the EU Flemish Cap survey ALKs to the 3NO length distribution indices. The recruitment index showed two good cohorts: one in the mid-1990s and another in early 2000.

**EU-Spanish 3L Survey (Flemish pass):** The EU-Spanish surveys in Div. 3L of NAFO Regulatory Area (Flemish Pass) was initiated by Spain in 2003. The Research vessel “Vizconde de Eza” has carried out the entire surveys series following the same procedures and using the same bottom trawl gear Campelen 1800. To know more details about the technical specifications of the surveys, see Román *et al.*, 2009. In 2003, the survey was carried out in spring (June) and it did not cover all strata adequately (69% of the total area prospected in 2006-2012).

In 2004, the survey was carried out in August, for a period of nine days, and it covered only the 96%. In 2005, it was not possible to perform the survey due to problems with the winch of the ship; and in 2006, for the first time, an adequate prospecting survey was conducted in Division 3L with over 100 valid hauls. Due to these coverage and technical problems only the series since 2006 is analysed. The Roughhead grenadier biomass index from this survey series were presented by Roman *et al.* (2019) and show in Table 6 and Figure 12. From 2006 to 2008 the biomass index was stable and since then presents a clear decreasing trend till 2012. In the period 2013-2015 the index increased to levels similar to the initial period. Between 2016 and 2018 the index shows a decreasing trend, reaching the minimum of the series in 2018.

There are not available surveys indices covering the total distribution, in depth and area, of this stock. Canadian Divisions 2J and 3K fall index and the Spanish research survey in Divisions 3NO have been considered as the best information available in order to monitor trends in resource status (NAFO 2010) because they cover depths down to 1,500 metres and, hence, cover the depth distribution of Roughhead grenadier fairly well (Murua and De Cardenas, 2005). Now there are available more surveys series cover depths down to 1,500 metres. Figure 14 presents the relative mean weight per tow (MWPT) for all the series available cover down to 1,500 meters depth. It can be seen an increasing period since 1995 till 2004-2008. There is a general decrease over the past decade with the exception of the Canadian 2J3K survey, which has increased.

## BIOLOGICAL STUDIES

Garabana *et al.* (2016) analyze the spatial and temporal variability of size and age at maturity of roughhead grenadier females in NAFO divisions 3LMN based on microscopic maturity staging and individual age readings. They found that spawning capable females are homogeneously distributed nearly year-round, but in scarce numbers what prevent to define a spawning season. This statement united to the high levels of atresia could indicate a reproductive migration. Figure 15 present the length at first maturity (L50) and the age at first maturity (A50) by year for the period 2005-2015. It was observed a clear decrease in length at first maturity (L50) of females from 27.8 cm in the period 2005-2011 to 25.6 cm in the last four years. The age at first maturity, A50, varied between 13.1 and 15 years, and there is not an evident trend of change over the years.

## ASSESSMENT METHODS

In previous years, different quantitative assessment models (XSA and ASPIC) were applied to the Subarea 2+3 RHG data (González-Costas, 2016). The fit of the data to these models has been very poor mainly due to lack of contrast and conflicting information from the available data. Therefore the results were not considered representative of the situation of the stock and the assessment that was approved was a qualitative one based on the survey information. This section tries to update the qualitative assessment.

### Qualitative assessment based on survey and fishery information.

This assessment is based on the survey trend and fishery information. There are not available surveys indices covering the total distribution, in depth and area, of this stock. Canadian Divisions 2J and 3K fall index and the EU survey in Divisions 3NO have been considered till 2010 as the best information in order to monitor trends in resource status (NAFO 2010) because they cover depths down to 1,500 metres and, hence, cover the depth distribution of Roughhead grenadier fairly well (Murua and De Cardenas, 2005). Since 2010, there are available more surveys series cover depths down to 1,500 metres (EU 3L and EU FC surveys).

Figure 14 presents the relative mean weight per tow for all the series available cover down to 1,500 meters depth. It can be observed a clear increasing trend in the period 1995-2008. Since then, there is a general decreasing trend with the exception of the Canadian 2J3K survey, which has increased.

Figure 16 presents the total catch / biomass (C/B) indices obtained using all the available survey biomass indices cover till 1400 m depth. The Canadian fall survey and the Spanish 3NO biomass (C/B) indices show a clear decrease trend from 1995 to 2007 and since then are more or less stable at very low level. The other (C/B)

indices (EU Flemish Cap, and EU 3L) started in the middle of the twenties and they show a stable low level similar to the Canadian fall and the EU Spanish 3NO surveys in this period.

Figure 17 presents the abundance series (MNPT) for ages 3 of the Canadian fall (2J+3K), the UE Div. 3NO survey and the EU Flemish Cap survey till 1400 m. The transformations of the lengths in ages were made applying the EU Flemish Cap survey ALK to the length indices for all series. Figures 6, 9 and 11 show the length and age distributions of the Canadian fall, EU-FC and EU 3NO indices. The tracking of cohorts in time is noisy and the estimated recruitment indices in size and age do not provide much information. In Figure 8 can be observed an increase in the abundance of small sizes (less than 10 cm) after 2010 until 2018.

The Z values estimated from average catch curves for the most important ages in the catches (6-13) based on Canadian 2J3K (1996-2015), EU-3NO (1997-2018), EU-FC till 1400 meters (2004-2018) and commercial catches information (1992-2018) are presented in Figure 18. The Z estimate from the catch curve based upon commercial catch at age data was 0.19 for ages ( $R^2=0.79$ ). The value estimate from the Spanish 3NO survey data was 0.21 ( $R^2=0.88$ ), for the Canadian 2J3K was 0.23 ( $R^2=0.90$ ) and for EU-FC was 0.14 ( $R^2=0.82$ ). The values estimated with different data sources are quite similar and estimated a Total mortality around 0.2.

### SUMMARY

There are not available surveys indices covering the total distribution, in depth and area, of this stock. Biomass indices from the surveys with depth coverage till 1400 meters are considered as the best survey information available to monitor trends in resource status because they cover the depth distribution of roughhead grenadier fairly well.

Biomass indices from the surveys with depth coverage till 1400 meters show a clear increasing trend in the period 1995-2008. Since then, there is a general decreasing trend with the exception of the Canadian 2J3K survey, which has increased.

With regard to fishing mortality (F), it can be observed that F proxies (Catches/biomass) shows a clear decrease trend from 1995 to 2007 and since then are more or less stable at very low level. The Z values estimated with the catch curve method with different data sources are quite similar and estimated a Total mortality around 0.2.

The estimated recruitment indices in size and age do not provide much information. An increase in the abundance of small sizes fish (less than 10 cm) after 2010 until 2018 can be observed in the surveys.

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**Table 1.** STACFIS Roughhead grenadier NAFO Subarea 2 and 3 nominal catches (t) by Division.

Year	STACFIS RHG Nominal catches (t) by Division									TOTAL
	2G	2H	2J	3K	3L	3M	3N	3O	Other	
1987					912	7	82			1001
1988		1			907		52			960
1989		2		3	289	28	11			333
1990		1	32		2211	688	312			3244
1991 <sup>a</sup>			12	113	2543	497	1093	10		4268
1992			23	274	2582	2961	760	125		6725
1993			10	193	996	1428	1680	61	27	4395
1994	1		2	35	585	2301	1062	28	9	4023
1995	22	6	16	16	1199	1625	1074	20	4	3982
1996					1945	888	1300	2		4135
1997	36	5	63	100	1774	922	1797	43		4740
1998					2766	2190	2230	84	92	7362
1999				61	2037	3127	1705	180	49	7159
2000				139	1382	2109	888	38	211	4767
2001				97	1465	753	754	48		3117
2002				147	1905	869	700	36		3657
2003 <sup>b</sup>	1	4	16	91	1342	886	1201	443		3984
2004	4	8	19	58	1310	844	897	42		3182
2005		1	15	93	642	457	235	13		1456
2006			21	54	696	488	111	6	44	1420
2007			10	22	294	191	146	1		664
2008	0	0	1	3	347	355	132	9		847
2009				6	379	136	102	6		629
2010			7	24	649	153	94	14		941
2011			1	61	426	294	224	1		1016
2012			3	14	652	511	119	5		1304
2013			1	1	202	146	48	0		398
2014			0	1	213	355	44			613
2015					116	78	37	0		231
2016					145	82	30	0		257
2017					273	62	48	1		384
2018					273	130	52	0		455

<sup>a</sup> Catch could not be well estimated; based on revised data is estimated to be 8000 to 14000 t. mixed roundnose and roughhead grenadiers. (Power and Parson 1988).

<sup>b</sup> In 2003, STACFIS could not precisely estimate the catch.

In 2011-2014 STATLANT 21A values

2015 and 2016 DCR values

2017-2018 CESAG values

**Table 2.** Roughhead grenadier Subarea 2 and 3 catches length distributions and ALK available by country and year.

Data Country	Length			ALK
	Spain	Portugal	Russia	Spain
1992	X	X		
1993	X			
1994	X			
1995	X	X		
1996	X	X		
1997	X	X	X	
1998	X	X	X	
1999	X	X	X	X
2000	X	X	X	X
2001	X	X	X	
2002	X	X	X	X
2003	X	X	X	X
2004	X	X	X	X
2005	X	X	X	X
2006	X	X	X	X
2007	X	X	X	X
2008	X	X	X	X
2009	X	X	X	X
2010	X	X	X	X
2011	X	X	X	X
2012	X	X	X	X
2013	X	X	X	X
2014	X	X	X	X
2015	X	X	X	X
2016	X	X	X <sup>1</sup>	X
2017	X	X	X <sup>1</sup>	X
2018	X	X	X <sup>1</sup>	X

In black only commercial information; in red commercial and Flemish Cap survey information

<sup>1</sup> Information no used due to the low sample level.

**Table 3.** Roughhead grenadier Subarea 2 and 3 total catches length distributions ('000) by year measure as pre anal fin length (AFL), samples and catches.

LENGTH Length (cm)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	30	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	4	0	3	0	0	0	0	15	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
6	12	7	5	0	0	0	0	8	0	1	1	4	3	0	0	0	0	0	0	1	1	0	0	1	0	0	1
7	12	12	16	4	0	10	7	12	4	3	5	22	24	1	2	0	1	2	4	3	6	1	9	5	44	2	2
8	11	29	33	8	3	63	21	45	32	16	16	44	39	3	8	4	3	12	21	25	37	5	54	15	140	81	4
9	39	115	67	43	17	121	57	126	112	59	59	102	70	6	19	10	10	42	68	38	80	15	95	39	151	321	10
10	69	51	159	308	212	287	221	157	224	150	162	233	168	12	56	21	22	84	166	99	177	40	225	44	155	500	27
11	101	65	132	231	328	518	448	278	327	210	238	333	256	20	99	32	56	178	284	220	354	66	364	86	65	279	37
12	146	100	150	306	647	529	687	517	474	343	378	444	350	41	157	48	137	243	552	532	740	128	677	127	57	78	61
13	223	255	212	314	771	515	835	651	714	519	492	456	399	93	147	51	138	166	312	336	458	60	223	68	36	63	66
14	531	288	370	412	796	654	1290	591	810	853	727	761	497	133	156	49	169	121	232	181	266	36	92	38	38	37	79
15	742	368	418	529	705	811	2241	698	863	912	950	951	552	167	187	58	201	119	208	172	192	39	128	39	32	44	76
16	755	623	517	515	569	943	2287	719	1038	719	967	1134	621	214	233	49	212	97	191	159	229	49	75	26	29	42	80
17	710	850	774	612	615	752	1777	807	1185	657	782	1005	632	277	234	47	216	64	127	141	155	53	64	30	29	36	73
18	678	802	813	681	653	642	1093	660	891	589	600	769	541	268	276	46	128	72	107	106	141	44	57	22	29	36	68
19	720	560	690	671	504	572	902	725	680	456	389	557	371	219	197	46	91	50	79	79	90	44	26	19	23	36	38
20	571	421	471	418	503	528	561	709	417	279	253	356	263	172	114	40	72	28	54	64	74	35	34	14	16	23	34
21	551	245	299	282	511	333	402	580	241	155	158	244	191	121	60	43	29	16	49	50	63	34	38	13	15	15	31
22	494	203	211	185	189	228	281	358	171	95	117	154	154	82	51	34	29	18	31	36	40	20	17	11	12	15	18
23	350	219	174	97	155	210	216	380	139	66	75	117	90	59	37	31	17	12	24	35	48	22	17	10	13	11	16
24	395	231	149	91	63	154	213	276	84	53	61	94	93	55	30	27	17	14	21	25	34	19	12	9	8	8	15
25	198	204	150	60	60	128	115	258	99	46	57	71	66	36	31	26	8	17	15	31	37	12	7	9	7	7	10
26	176	188	113	66	62	79	96	167	96	41	50	49	43	22	18	23	11	16	19	29	28	10	10	7	6	6	14
27	121	109	88	73	14	47	49	166	65	32	40	45	41	23	16	20	19	10	15	28	26	12	4	5	4	4	10
28	131	74	64	59	50	45	74	125	44	29	43	36	29	14	21	18	6	10	7	21	20	8	3	3	2	3	10
29	117	75	47	48	60	54	29	87	37	24	42	26	27	12	12	15	2	7	2	13	18	7	3	3	2	2	3
30	64	52	49	17	85	41	30	69	14	19	31	39	22	8	9	10	1	6	3	11	19	7	3	2	2	1	11
31	46	50	28	31	17	35	38	70	21	18	25	21	20	7	6	8	1	4	3	3	11	2	3	1	0	1	4
32	38	55	28	25	0	23	57	60	18	8	21	13	17	9	7	4	5	6	2	3	5	2	1	0	0	1	3
33	22	11	15	15	0	27	12	73	9	9	16	7	7	8	4	3	1	2	2	2	3	1	0	0	0	1	3
34	17	13	15	9	10	18	14	35	10	9	12	8	7	4	7	3	0	2	1	1	2	1	1	0	0	1	2
35	8	9	9	1	0	6	13	21	9	7	10	9	5	5	5	2	1	3	0	0	0	1	0	0	0	0	0
36	8	4	3	0	0	5	11	21	18	3	8	6	2	4	1	1	1	0	0	0	0	1	0	0	0	0	0
37	1	1	4	4	0	0	7	9	15	2	2	2	2	5	1	1	0	1	0	1	1	0	0	0	0	0	0
38	0	0	3	0	0	1	2	9	0	1	1	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0
39	1	0	0	0	0	2	0	2	0	2	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0
40	14	0	2	0	0	2	0	0	12	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<b>TOTAL</b>	<b>8080</b>	<b>6291</b>	<b>6281</b>	<b>6114</b>	<b>7598</b>	<b>8385</b>	<b>14085</b>	<b>9584</b>	<b>8875</b>	<b>6386</b>	<b>6789</b>	<b>8114</b>	<b>5609</b>	<b>2104</b>	<b>2208</b>	<b>770</b>	<b>1606</b>	<b>1423</b>	<b>2598</b>	<b>2446</b>	<b>3356</b>	<b>775</b>	<b>2241</b>	<b>643</b>	<b>916</b>	<b>1656</b>	<b>809</b>
<b>(Sp+Pt+Rus) Catch (t)</b>	<b>6125</b>	<b>2054</b>	<b>1720</b>	<b>3923</b>	<b>3874</b>	<b>4500</b>	<b>7231</b>	<b>7053</b>	<b>4555</b>	<b>2954</b>	<b>3254</b>	<b>3869</b>	<b>2934</b>	<b>1157</b>	<b>1182</b>	<b>530</b>	<b>685</b>	<b>575</b>	<b>805</b>	<b>780</b>	<b>1185</b>	<b>269</b>	<b>459</b>	<b>188</b>	<b>233</b>	<b>350</b>	<b>415</b>
<b>Samples</b>	<b>219</b>	<b>48</b>	<b>288</b>	<b>234</b>	<b>229</b>	<b>225</b>	<b>34</b>	<b>164</b>	<b>214</b>	<b>299</b>	<b>276</b>	<b>150</b>	<b>188</b>	<b>106</b>	<b>152</b>	<b>97</b>	<b>61</b>	<b>133</b>	<b>104</b>	<b>45</b>	<b>56</b>	<b>40</b>	<b>52</b>	<b>51</b>	<b>52</b>	<b>42</b>	<b>63</b>
<b>Total catch (t)</b>	<b>6725</b>	<b>4395</b>	<b>4023</b>	<b>3982</b>	<b>4135</b>	<b>4740</b>	<b>7270</b>	<b>7160</b>	<b>4767</b>	<b>3117</b>	<b>3657</b>	<b>4179</b>	<b>3290</b>	<b>1456</b>	<b>1420</b>	<b>664</b>	<b>847</b>	<b>629</b>	<b>943</b>	<b>1016</b>	<b>1303</b>	<b>389</b>	<b>595</b>	<b>231</b>	<b>257</b>	<b>384</b>	<b>455</b>





Mean Weight (gr)																													
Age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2007	2008	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	11		16				30	10	14	13	22	34	4	4		68													
2	40	51	49	80	165	107	107	127	116	99	61	91	41	62	16	93	68			90		31	35	28	38	38	42	32	26
3	86	77	85	113	156	147	143	180	158	137	154	148	102	80	109	105	102	52	56	118	38	53	57	72	52	77	67	71	83
4	119	111	115	143	184	211	177	244	194	176	218	213	192	114	161	161	167	90	97	164	98	90	105	95	96	125	115	111	136
5	186	184	173	230	216	262	229	317	243	227	268	278	269	195	212	256	245	147	162	212	165	138	137	136	144	172	194	138	211
6	258	236	236	325	260	300	281	365	276	271	306	299	317	262	265	383	342	213	227	262	220	179	182	178	179	239	275	271	295
7	337	320	313	434	348	355	342	434	327	324	353	333	375	343	343	410	397	305	302	321	297	239	261	247	253	285	382	398	406
8	440	414	412	524	451	421	403	487	393	397	414	423	473	437	434	516	503	423	426	444	396	364	378	371	359	399	469	508	481
9	594	500	509	612	560	516	490	591	498	499	498	483	568	538	561	619	602	494	486	556	549	479	516	502	505	520	544	595	564
10	748	585	590	677	653	618	600	677	568	587	607	616	726	669	609	848	807	527	566	648	744	638	656	664	720	664	640	721	755
11	922	736	716	776	767	743	749	785	725	709	692	854	836	810	788	1095	1116	665	686	817	887	849	898	872	853	889	856	890	905
12	1063	886	836	885	851	855	876	949	828	824	840	979	1072	988	1023	1199	1203	832	853	1067	1135	1103	1121	1081	1058	1077	990	1044	1106
13	1226	1101	1039	1106	984	1033	1052	1151	1068	1033	989	1155	1361	1131	1282	1655	1589	1308	1325	1287	1416	1341	1332	1381	1365	1357	1149	1209	1123
14	1446	1324	1280	1443	1245	1252	1299	1305	1353	1343	1412	1521	1546	1198	1709	1876	1829	1209	1268	1544	1689	1561	1637	1645	1858	1565	1370	1570	1536
15	1683	1546	1530	1705	1696	1534	1544	1657	1561	1652	1565	1903	2234	1783	2160	1957	2119	816	1590	1617	1808	1752	1958	1915	1688	1730	1627	1685	1891
16	1928	1777	1729	1966	1837	1799	1823	1832	1787	1851	1852	1998	2330	2282	2457	2374	2375	1703	1909	1914	2266	1974	2217	2143	1778	1912	1899	1890	2146
17	2212	1989	2005	2220	2083	2257	2100	2023	2010	2132	2078	2407	2393	2578	2808	3715	2903	1853	2026	2301	2509	2316	2425	2233	2419	2352	2052	2199	2262
18	2478	2326	2333	2459	2197	2421	2466	2358	2441	2429	2440	3056	2496	2948	3377	2527	2786	1586	1788	2459	2655	2384	2673	2536	2440	2367	2412	2848	2620
19	2669	2508	2553	2643	2283	2534	2707	2474	2716	2662	2822	2954	2675	3426	3502	3065	2741	3220	3241	2562	2923	2575	2803	2745	3047	2973	2053	3304	3801
20	3052	2777	2889	2887	2643	2870	2942	2887	3207	3000	3140	2899	2719	3199	4089	3251	3269	1995	2037	2843	2997	2779	2851	2826	3056	3565	2733	4313	2426
21	3363	2898	3076	3029	3105	3198	3063	3036	3739	3263	2939	4177	3773	3411	5186	4213	3031	3639	3837	3465	3192	2971	3806	3622			3314	4188	
22	3993	3422	3637	3487	3192	3471	3663	3584	3851	3754	3807	3682	4384	4287		3830	4255	4255	3757	3477	3841	2868		4506	3834			5245	
23	4092	3299	3525	3556	2514	3485	3592	3699	4289	3787	3240	4206	4534	3476		3369	3830			3126	3549	4169		3829		4298		5245	
24	4998	4172	4453	4067		4541	4108	4442	4670	4493	4206	4220	4820							2873	4384	4062	4648	3408	2699				





**Table 5.** Available surveys biomass indices for the roughhead grenadier Subareas 2 and 3 stock, with their depth and area coverage.

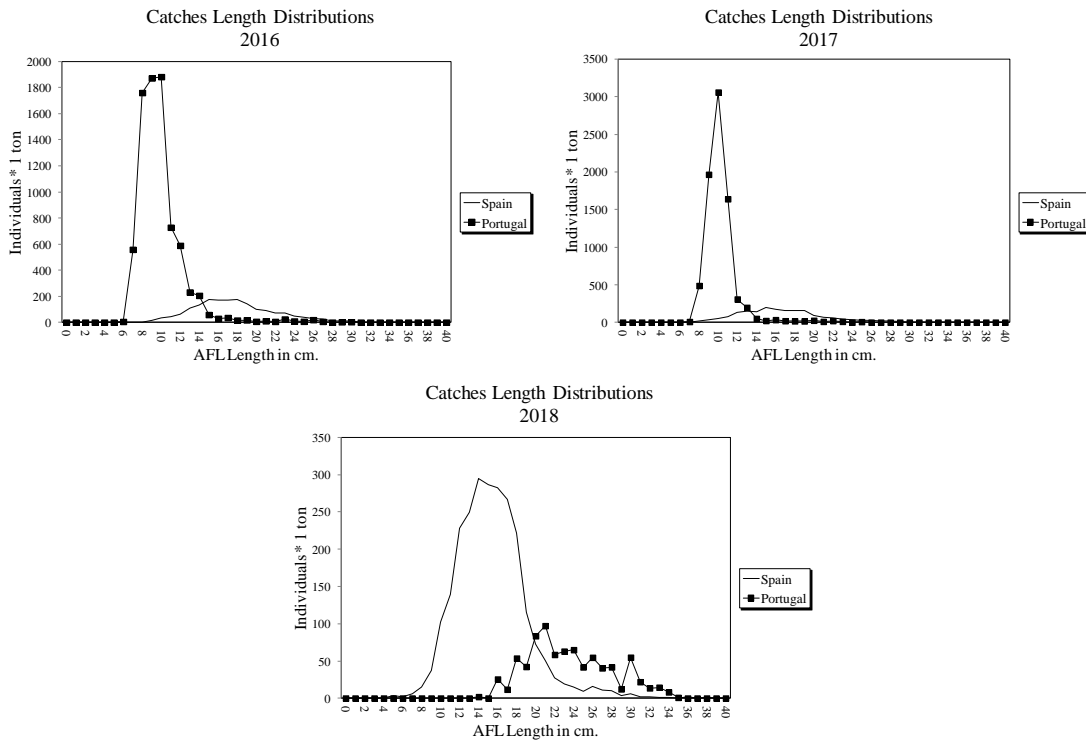
Survey	Time Series	NAFO Division	Depth Range
Canadian Fall Survey	1978 - 1994	2GHJ 3KLMNO	<730 m
	1995 - 2018	2GHJ 3KLMNO	<1500 m
EU-Spanish Surveys in Div. 3NO	1997 - 2018	3NO	<1500 m
EU-Spanish Surveys in Div. 3L (Flemish pass)	2003-2004; 2006- 2018	3L	100-1500 m.
EU Flemish Cap Surveys	1988 - 2003	3M	<730 m
	2004- 2018	3M	<1500 m
Canadian Spring Survey	1991 - 2018	3LNO	<730 m
Canadian deepwater	1991, 1994, 1995	3LMN	<1500 m
Russian	2001 - 2002	3M	120 - 1280 m
EU Deepwater	1996	3LMN	700 - 3100m





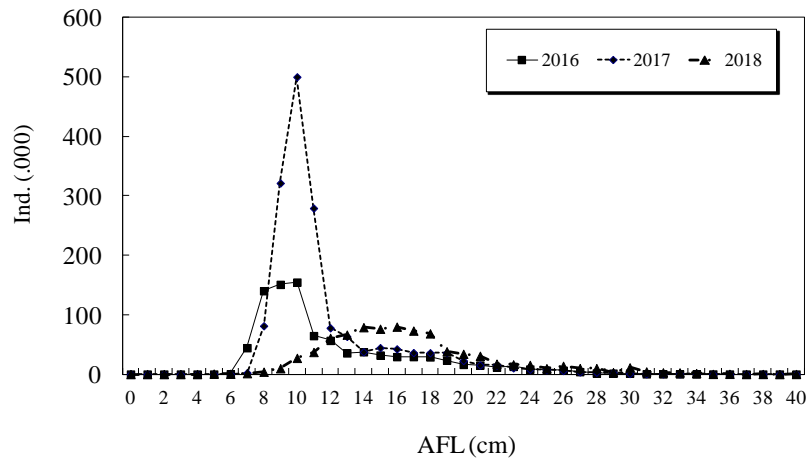


**Figure 1.** STACFIS roughhead grenadier NAFO Subarea 2 and 3 nominal catches (t).

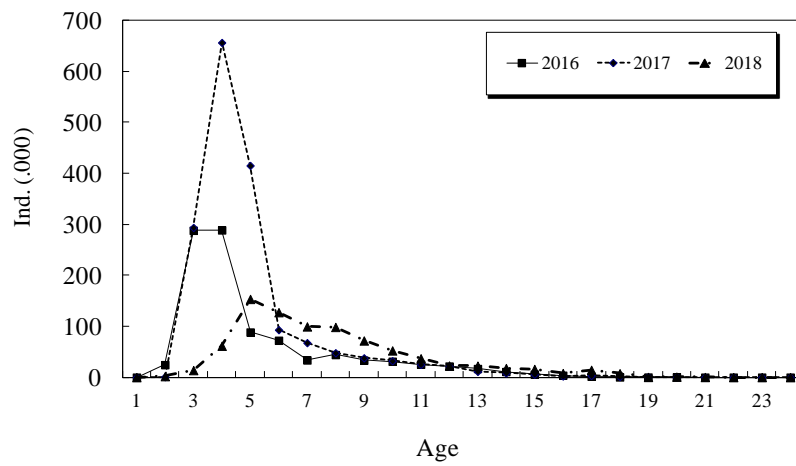


**Figure 2.** Subarea 2+3 roughhead grenadier Spanish and Portuguese catches length distributions (individuals per ton) for 2016-2018.

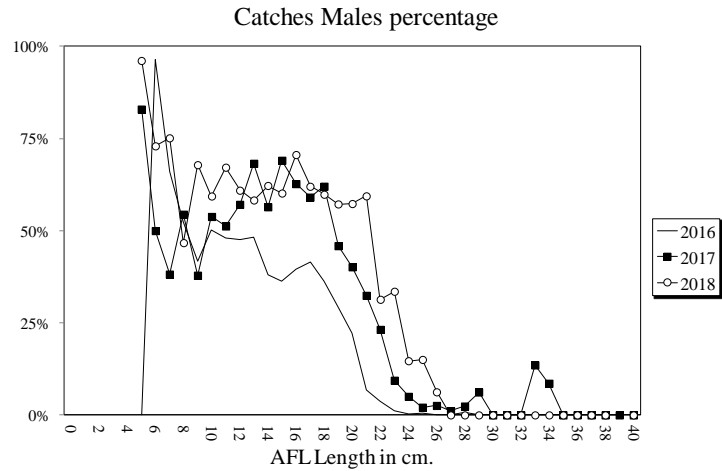
### Total Catches Length Distributions



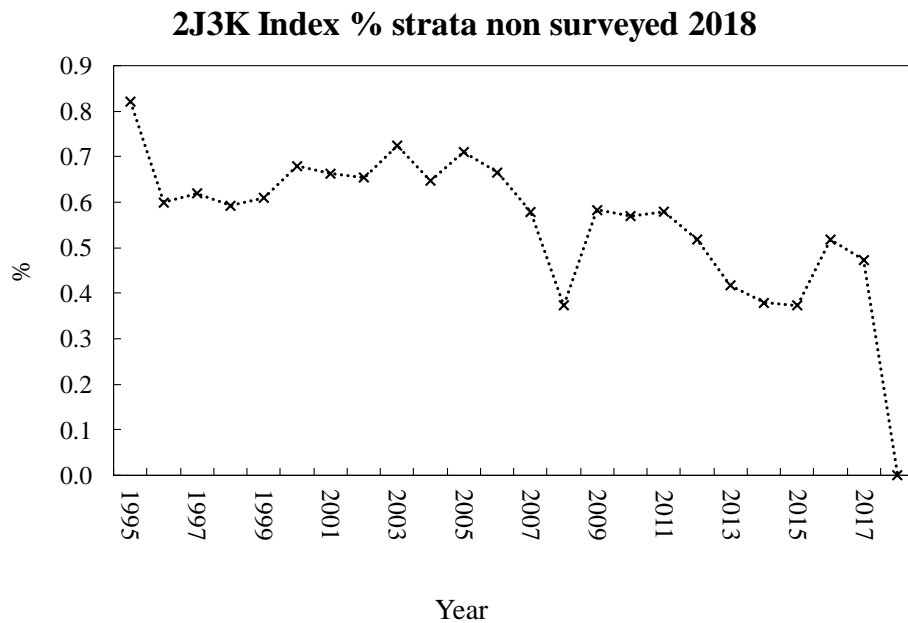
### Total Catches Age Distributions



**Figure 3.** Subarea 2+3 roughhead grenadier total catches length and Age distributions for 2016-2018.

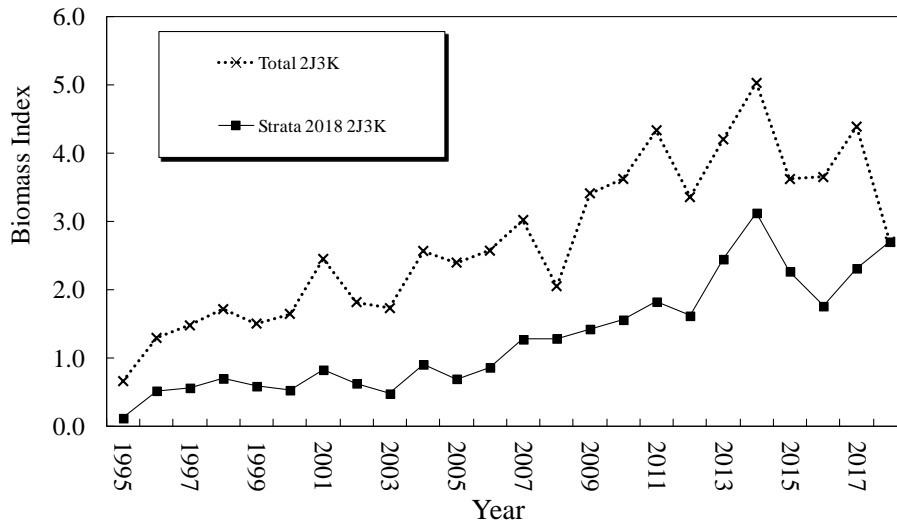


**Figure 4.** Subarea 2+3 roughhead grenadier sex ratio by length for 2016-2018. Based on the Spanish and Portuguese commercial length samples.

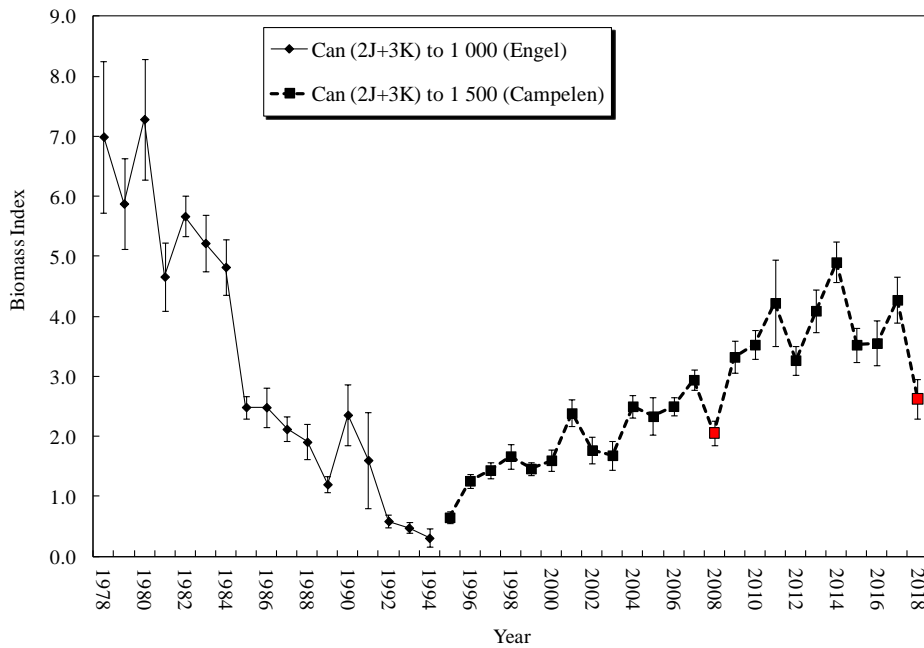


**Figure 5.** Percentage of the 2J3K index (MWPT) in the strata non surveyed in 2018 for the RHG.

### 2J3K Total and strata surveyed in 2018

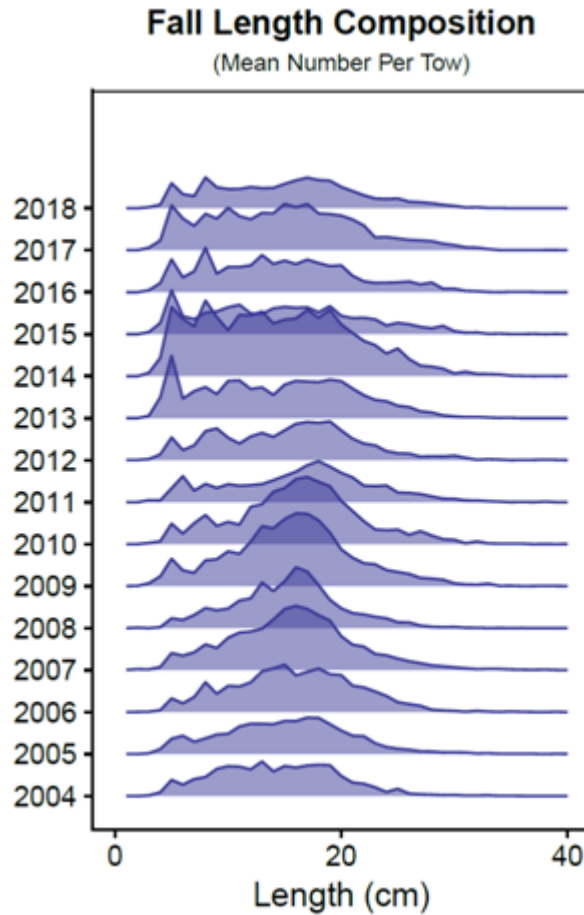


**Figure 6.** Index 2J3K (MWPT) for the RHG. The dot line show the index estimated with all the 2J3K strata and the line show the index estimated only with the strata surveyed in 2018.

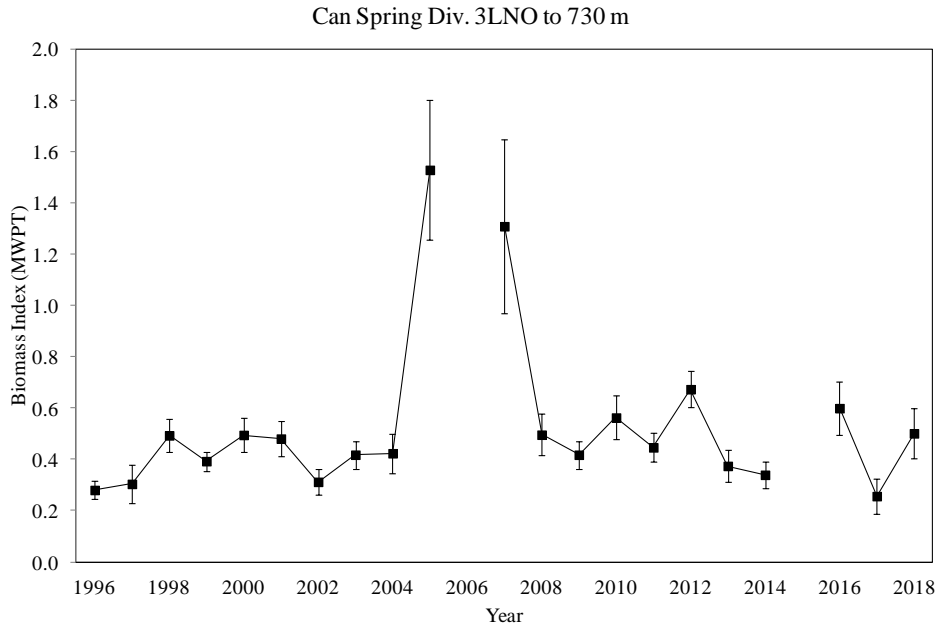


**Figure 7.** Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the Canadian autumn (Div. 2J3K) survey. In red years with coverage problems.

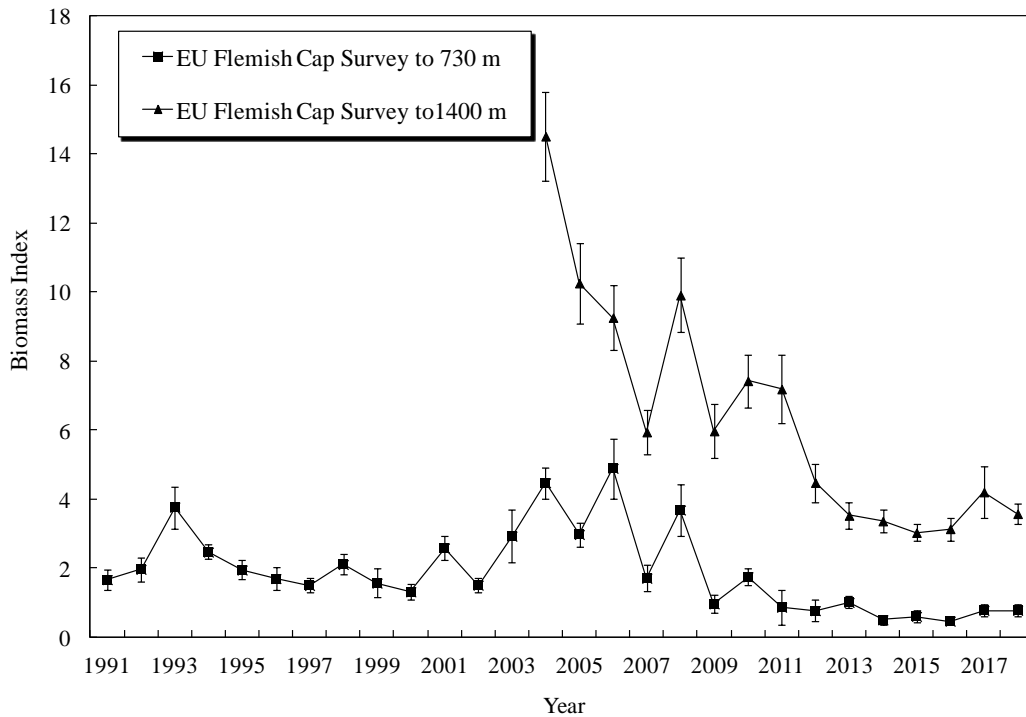




**Figure 8.** Roughhead Grenadier (*Macrourus berglax*) in SA2+3 Canadian Fall length distributions presented by Rideout R.M., D.W. Ings, 2019. Data for Divs. 2J3KLNO (2H has been excluded).

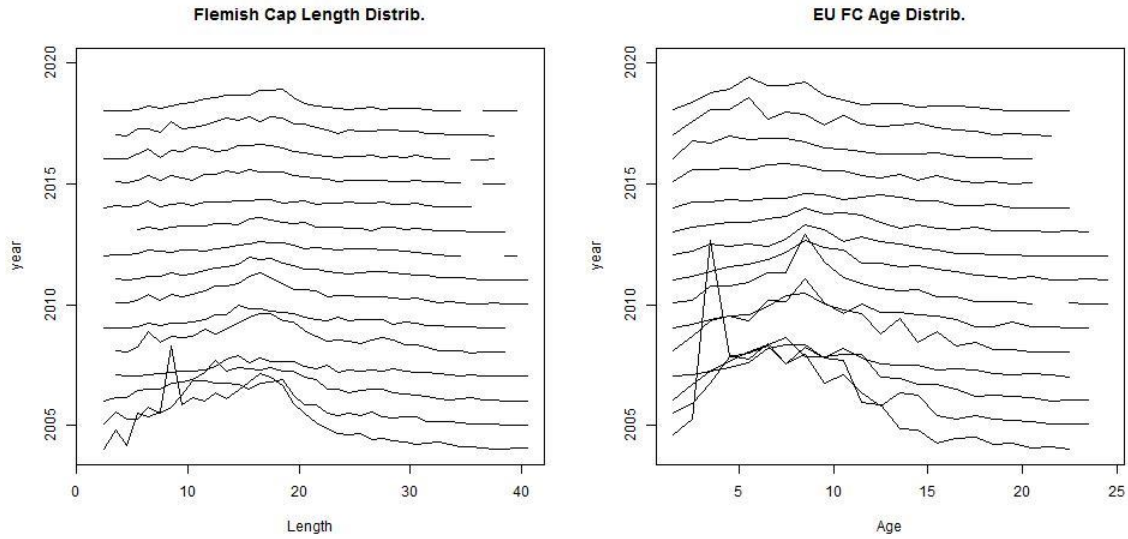


**Figure 9.** Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the Canadian spring surveys (3LNO).

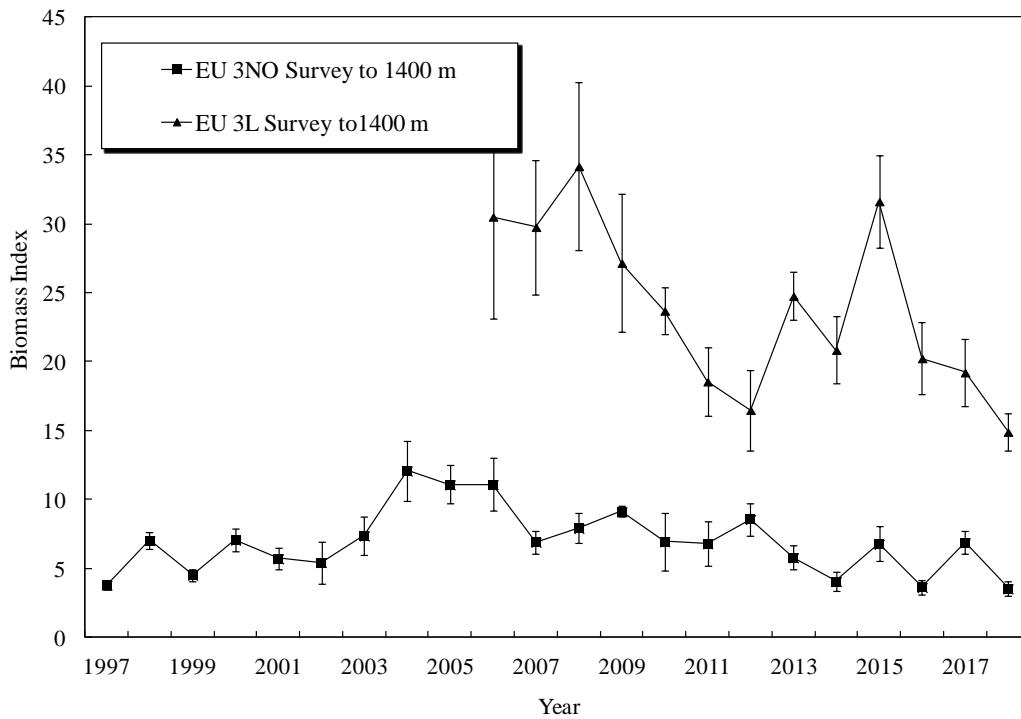


**Figure 10.** Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the EU Flemish Cap survey.



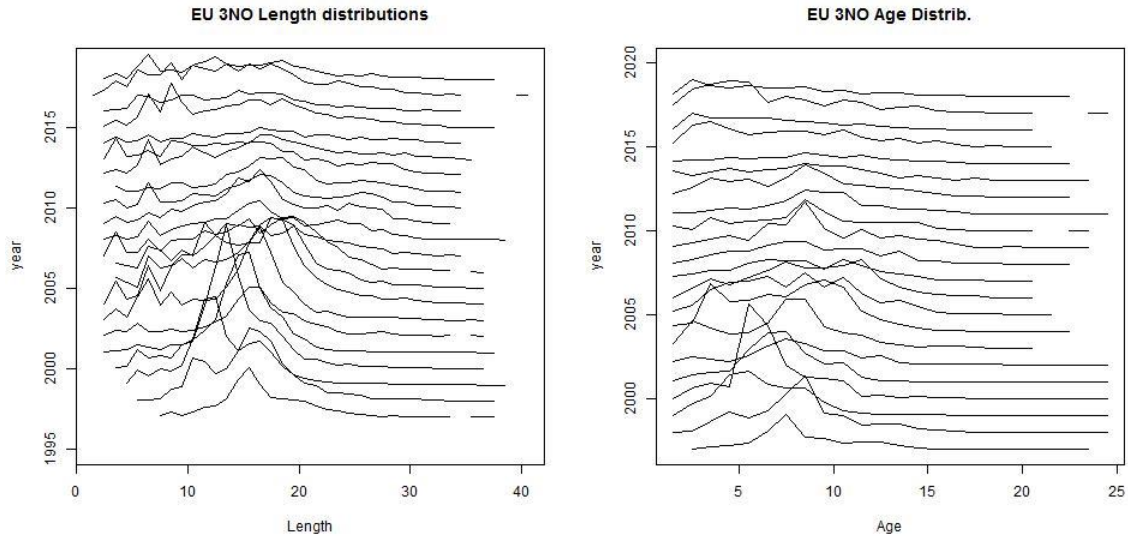


**Figure 11.** Roughhead Grenadier length and age frequency distribution from EU Flemish Cap surveys (Div. 3M).

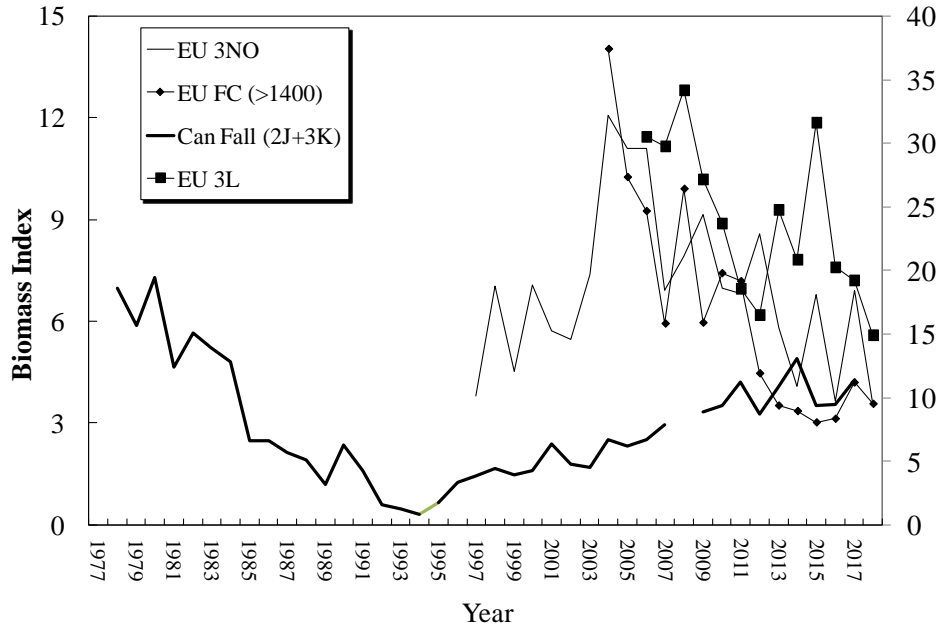


**Figure 12.** Roughhead grenadier in Subareas 2+3: biomass index (+/- SE) from the EU Spanish Div. 3NO and 3L surveys.

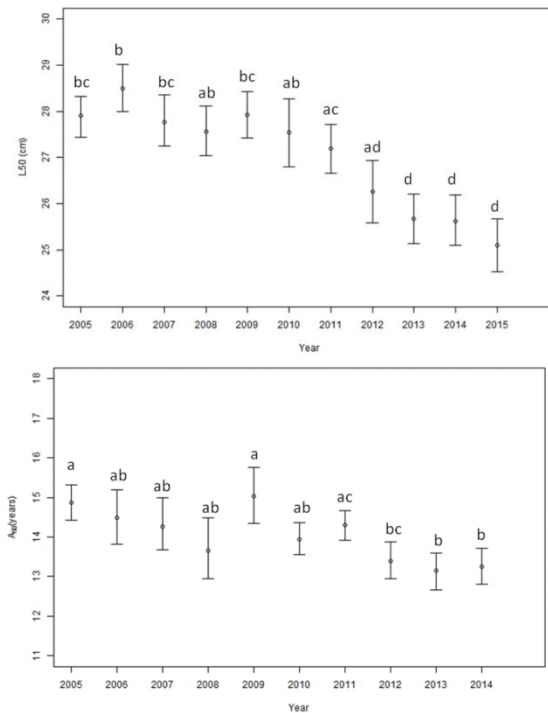




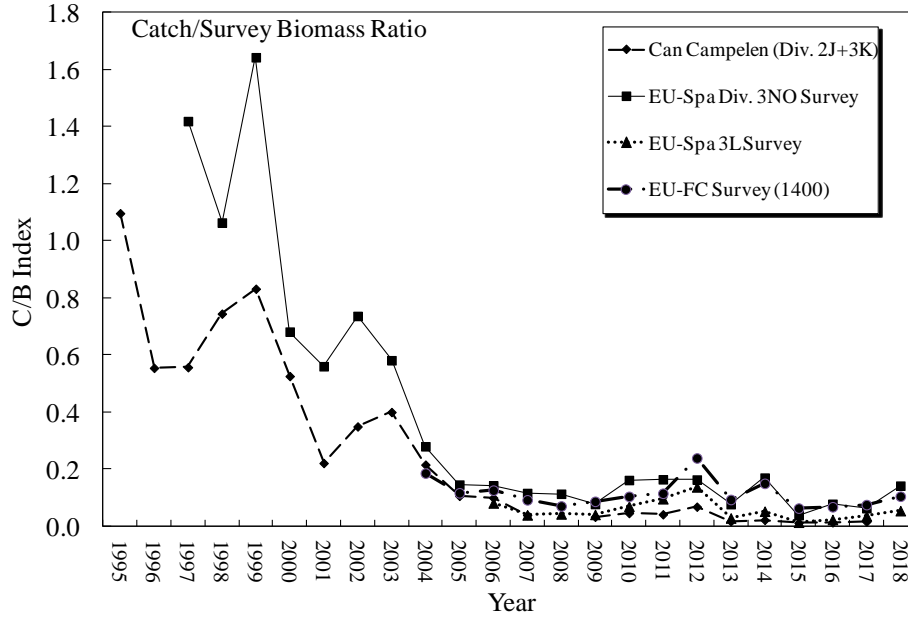
**Figure 13.** Roughhead Grenadier length and age frequency distribution from EU 3NO survey.



**Figure 14.** Roughhead grenadier in Subareas 2+3: MWPT biomass indices from Canadian fall 2J+3K (1978-2017), EU 3NO (1997-2018), EU 3L (2006-2018), and EU Flemish Cap till 1400 m.(2004-2018) surveys.

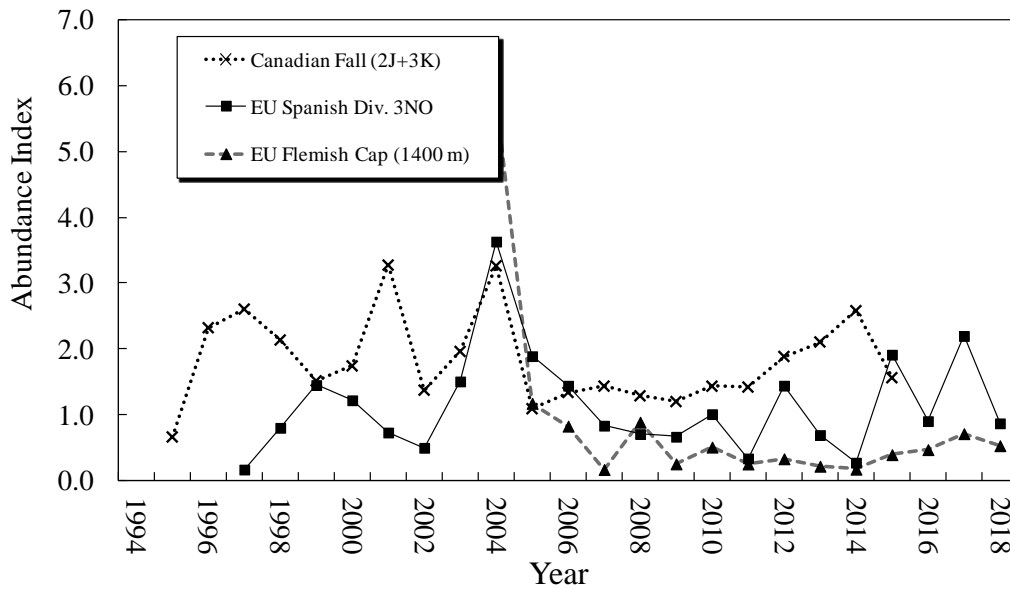


**Figure 15.** L50 and A50 estimation with correspondent bootstrap confidence intervals at 95% by year. Between years post hoc differences in maturity ogives are marked with letters. Identical letters denote no significant differences among years.

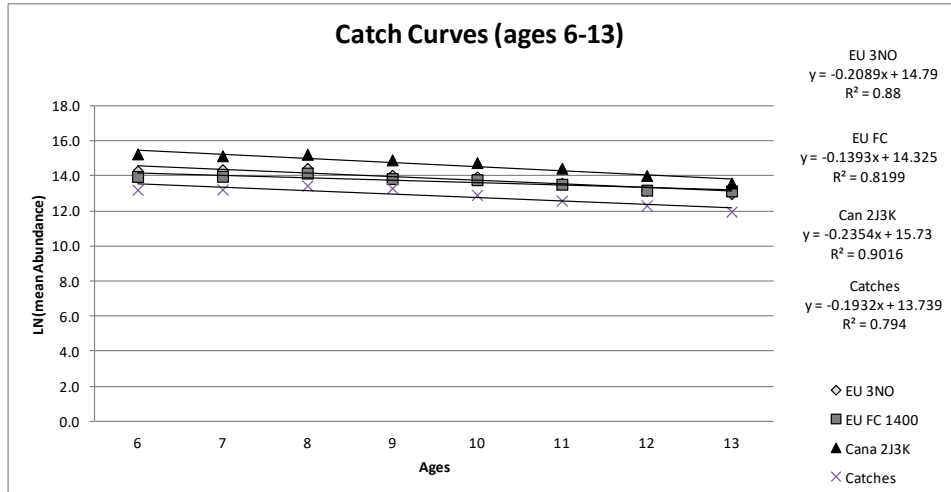


**Figure 16.** The catch / biomass (C/B) indexes obtained using the Canadian fall survey (2J+3K), the EU Spanish 3NO, EU Spanish 3L and the EU Flemish Cap (till 1400 m) biomass indices in the period 1995-2018.

### Surveys Recruitment Indices (age 3)



**Figure 17.** Roughhead grenadier in Subareas 2+3: Canadian Fall (2J+3K), EU Spanish Div. 3NO survey and EU Flemish Cap (1400 m) survey abundance (MNPT) at ages 3.



**Figure 18.** Z values estimated from average catch curves for the most important ages in the catches (6-13) for commercial catches (1992-2018), Canadian Fall (2J+3K) (1996-2015) EU Spanish 3NO survey (1997-2018) and Flemish Cap survey till 1400 m (2004-2018).