Monitoring of the benthic community in Hlaðseyri 2013- 2015

Worked for Fjarðalax

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INTRODUCTION

Fjarðalax asked Náttúrustofa Vestfjarða (NAVE) to monitor sea bottom sediment around the aquaculture area located in Hlaðseyri in the fjord of Patreksfjörður, NW Iceland (figure 1). This mariculture system comprised six cages each with a diameter of 30 meters. Salmon was stocked in June 2012 and the harvest was completed in July 2014.

Accumulation of organic waste is a well know outcome of aquaculture practice. The effects on the benthic community are usually greatest directly under the cages and in the immediately surrounding area (Johannessen et al.1994, Karakassis et al. 1999, Kutti et al. 2007). Various factors, such as sea currents, topography, number of cages, fish density and type of feed, shape and size the area that is mainly affected by aquaculture organic waste.

The aim of this study was to examine how long the aquaculture area in Hlaðseyri took to recover after the stress caused by the farming. To accomplish this aim, benthic animal communities were examined by sampling six stations at three different times, during and after the farming.

Interpretation of aquaculture effects need to take into consideration several traits of the macrofauna community such as its composition, its diversity and the presence or absence of certain indicator species (Pearson & Rosenberg 1978, Rygg 2002, Dean 2008).

Previous studies on the benthic community had been performed in Hlaðeyri (Asle Guneriussen & Rune Palerud 2003, Böðvar Þórisson *et al*. 2012, Ólafsdóttir S.H. 2015) and sea currents have been measured at least on two occasions (Asle Guneriussen & Rune Palerud 2003, Héðinn Valdimarsson unpublished data 2012).

Figure 1. View from Hlaðseyri with the town of Patreksfjorður to the right.

MATERIALS AND METHODS

Sampling

This survey was intended to investigate the soft bottom animal communities on six stations placed at varying distance from the aquaculture cages. Station (st.) A at 240 m from the cages, st. B at 100 m, st. C at 75 m, st. D at 50 m, st. E at 25 m and st. F at the cage (figure 2). Station I was sampled only in 2015 and was positioned between the cages, in proximity of cage B2. All the six stations were sampled on three different times; during the salmon growing period (November 9th 2013), after the harvest was complete (September 4th 2014) and after circa 9 months of no use of the farming area (May 21st 2015).

Sampling was conducted from a boat by using a Van Veen grab with 250 cm^2 of sampling area. Three samples were taken for each station; sediments were described in colour, consistency and smell. Samples were then submerged with a fixative solution of formaldehyde (5-10%) and a consequential amount of borax. Formaldehyde solution was substituted with an ethanol solution (70%) after 4-5 days.

For each station geographical coordinates, depths, distances from cages are in table 1, sample descriptions are in table 2.

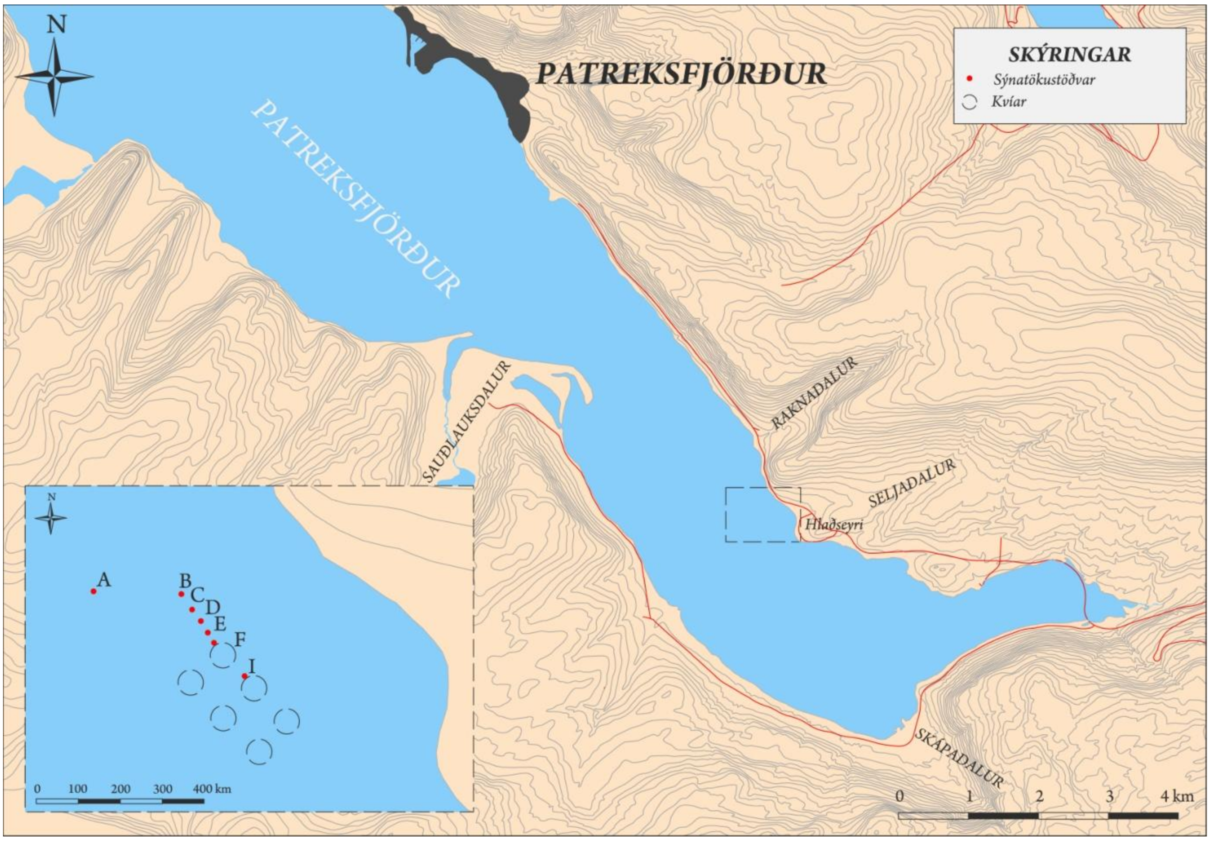

Figure 2. Map of the monitoring area in Hlaðseyri. Map: NAVE/HBA.

Table 1. Position, depth of stations and their distance from the cages.

Station	Gps coordinates *decimal minutes*	Dept (m)	Distance (m)
A	N65 32.565 W23 53.721	ca 40	240
B	N65 32.570 W23 53.450	ca 40	100
C	N65 32.551 W23 53.413	ca 40	75
D	N65 32.538 W23 53.384	ca 40	50
E	N65 32.523 W23 53.359	ca 40	25
F	N65 32.511 W23 53.338	ca 40	0
I	N65 32.472 W23 53.236	ca 40	0

Table 2. Description of samples.

St.	**2013**		**2014**		**2015**	
	Description	Smell	Description	Smell	Description	Smell
A	Black-brown mud, shell fragments	No	Black mud, shell fragments	No	Black-brown mud	No
B	Black mud/sand, shell fragments	No	Black mud	No	Black mud/sand, shell fragments	No
C	Black mud/sand, shell fragments	No	Black mud, shell fragments	No	Black mud/sand, shell fragments	No
D	Black mud/sand, shell fragments	Little	Black thick mud	No	Black mud/sand, shell fragments	No
E	Black mud/sand	Little	Black thick mud	Yes	Black mud/sand	Little
F	Black jelly mud	Yes	Black jelly thick mud	Yes	Black jelly mud	Little
I					Black-brown mud, shell fragments	Little

Treatment of samples

The samples were sieved through a 500 µm sieve with running water. The animals were successively collected counted and identified to the lowest feasible taxonomical level using a Leica MZ 6 or a MZ 12 stereoscope. Foraminifera, if present, were not collected.

Statistical analyses

Univariate analysis was performed using the Primer 6 program (Clarke & Warwick 1994). The Shannon-Wiener diversity index (H’) and Evenness index (J´) were calculated (Grey et. al 1992; Brage og Thélin 1993). To avoid artificial inflation of diversity few taxa were grouped together (for example Nepthys caeca and Nepthys sp) and Nematodes worms were not included in the calculation. Table 5 used for statistical computations is in appendix 2.

Shannon-Wiener index H´:

$$H' = -\sum_{i=1}^{S} p_i \, log_2 p_i$$

where:

S = number of taxa,

pi = fraction of the entire population made up of species

Evenness index (J´) describes how close in number of individuals each species is with others. Is based on the Shannon-Wiener index (H´) and is mathematically defined as:

Evenness index J´:

$$J' = \frac{H'}{H'_{max}}$$

Where H´max=

$$H'_{max} = -\sum_{i=1}^{S} \frac{1}{S} \, log_2 \frac{1}{S} = log_2 S$$

RESULTS

Table 4 in Appendix 1 gives a complete list of all identifiable taxa in the benthic community samples. All values represent the average of three samples adapted to 1.0 m^2.

Figure 1 depicts species abundance of all samples showing reduction in abundance across years and the total absence of benthic fauna in station F for the year 2013.

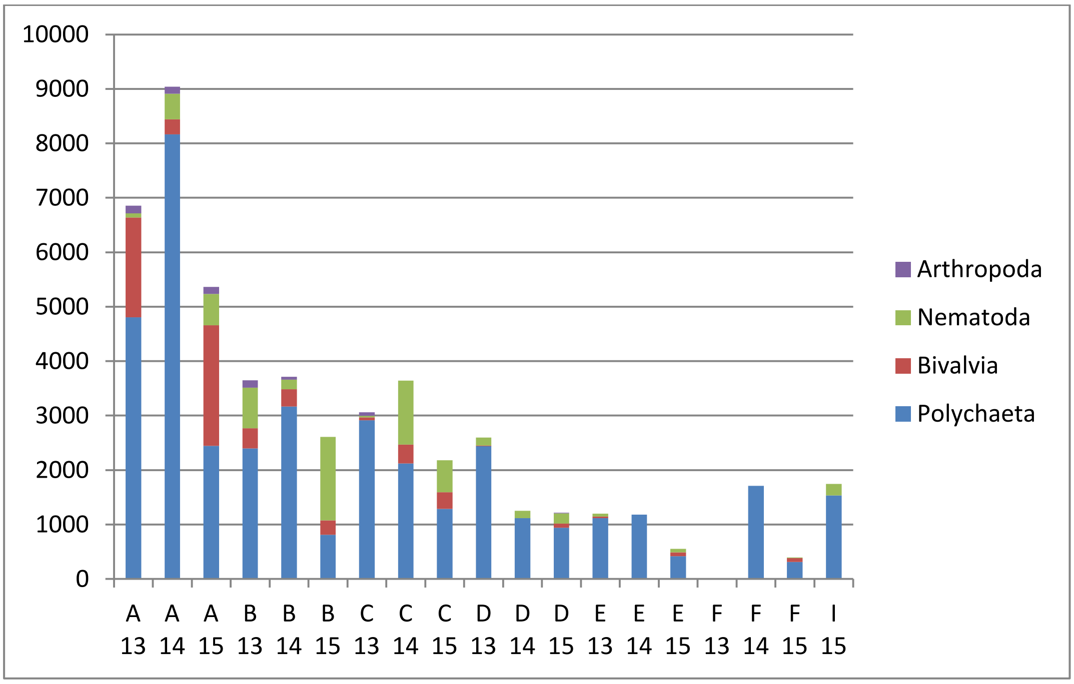

Figure 3. Abundances for 4 main classes of macrofauna community in Hlaðseyri.

Annelids Polychaeta were the most abundant class in all stations except two; in station A 15 their abundance was similar to the Mollusc Bivalves and in the station B 15 only Nematodes worms were more abundant. Annelids Polychaeta comprised 30 taxa and 38889 individuals (75% of the total numbers across all samples). Bivalves were the second most abundant class with 5 taxa and 6245 individuals (12%) followed closely by Nematodes with 6173 (12%). Arthropods comprise only 1% of all fauna and they were absent at most of the stations.

There was a general decline in the number of individuals from station A (far from the cages) to station F (closer to the cages) except for the station F 14, but this station was characterized only by the presence of polychaetes. Bivalves were most frequent in stations A (A13 and A15) but their numbers declined on the stations approaching the cages. Nematodes are present in almost all stations but show high abundance in station B15 and C14 (figure 3).

Results from the analyses with Primer 6 (table 3) (Nematodes are excluded from these calculations) tells us about the number of taxa (S) included in the stations. This feature had very variable values from 21 (A13) to 3 (F14 and I15) and generally declining while approaching the cages. Number of taxa and diversity index values show a positive increase in the year 2015 for all the stations except for station A. This increase is smaller the further the station is from the cages. These values differ less between stations in 2015, except for station I (table 3, figure 4 and 5).

Values of the diversity index H' (log_2) is highest at just above 3 in station A 15 and lowest at 0,92 in station F 14 (F 13 because of total lack of fauna did not give any value). All stations show an increase in H´ for the sampling performed in the last year. Although the trend between years show 2 different patterns, stations A and B had a decrease in the year 2014 and an increase in 2015 while all other stations show a constant increase from 2013 to 2015 (figure 5).

Table 3. Number of taxa, abundance, Evenness index and Shannon-Wiener diversity index for the stations in Hlaðseyri 2013-2014-2015 (Nematodes are exclude from calculation).

Stations	S	N	J'	H'(log_e)	H'(log_2)	H'(log_{10})
A 13	21	6639	0,63	1,92	2,78	0,84
A 14	17	8547	0,36	1,01	1,45	0,44
A 15	16	4792	0,77	2,14	3,09	0,93
B 13	14	2810	0,67	1,78	2,57	0,77
B 14	12	3566	0,57	1,40	2,03	0,61
B 15	16	1077	0,70	1,94	2,80	0,84
C 13	9	3035	0,45	0,99	1,43	0,43
C 14	8	2469	0,73	1,52	2,20	0,66
C 15	15	1593	0,76	2,06	2,97	0,89
D 13	7	2453	0,47	0,92	1,33	0,40
D 14	8	1117	0,47	0,97	1,41	0,42
D 15	19	1037	0,63	1,87	2,69	0,81
E 13	7	1144	0,53	1,03	1,49	0,45
E 14	6	1184	0,71	1,27	1,83	0,55
E 15	12	487	0,69	1,71	2,47	0,74
F 13	-	-	-	-	-	-
F 14	3	1710	0,58	0,64	0,92	0,28
F 15	11	381	0,85	2,03	2,92	0,88
I 15	3	1535	0,53	0,58	0,84	0,25

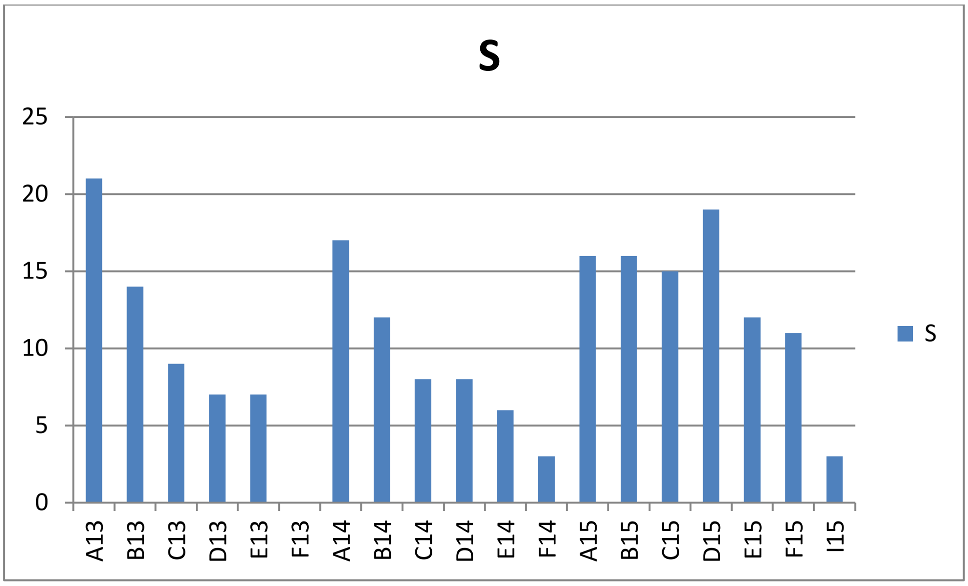

Figure 4. Number of taxa for stations in Hlaðseyri 2013-2014-2015.

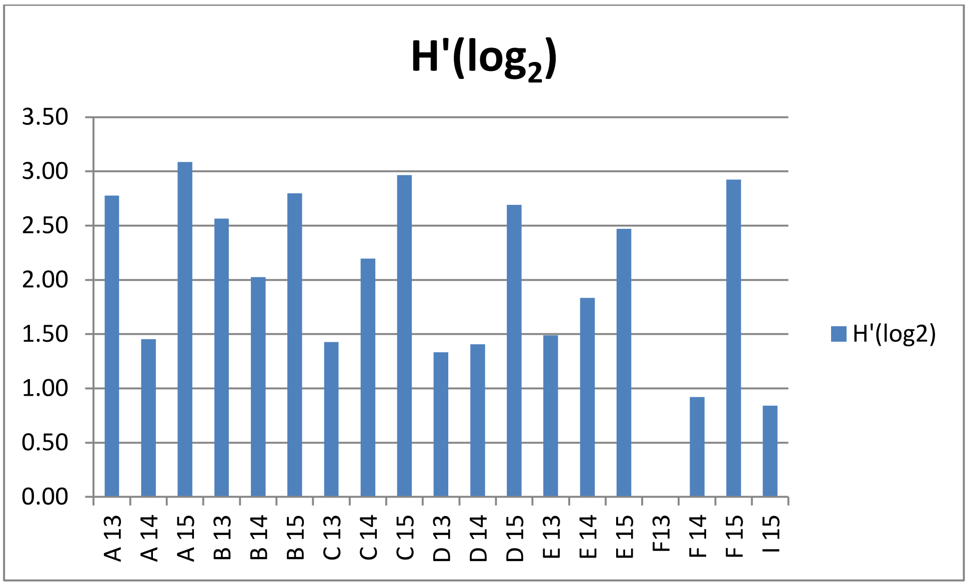

Figure 5. Shannon-Wiener diversity index in log_2 for the stations in Hlaðseyri 2013-2014-2015.

In the most represented class (Polychaeta worms) there are 3 species that stand out, *Cossura longocirrata* (10.655 ind.), *Capitella capitata* (8.358 ind.) and *Microphthalmus aberrans* (8.238 ind.). *Capitella capitata* is a notorious indicator species of organic enrichment in mariculture (Pearson & Rosenberg 1978, Rygg 2002, Dean 2008). Its presence was null at station A for all the 3 sampling years while its abundances showed different yearly patterns. In the year 2013 this value (around thousand individual per m^2) decreased by approaching the cages until 0 in station F. Year 2014 values were higher at stations B and F but similar at the other 3 stations. In the year 2015 the abundance is much lower (less then hundred individuals per m^2) with the top value in station F. Station I reached up to 348 ind. /m^2. Conversely, *Cossura longocirrata* was never present at station F and with the highest abundance at station A for all 3 sampling times. *Microphthalmus aberrans* was present at all stations expect for F 13 and I 15, but more numerous at the half way stations B, C and D.

Less abundant but still above thousand individuals were; *Eteone longa* very few individuals in the sampling of 2013 and only in station A, fairly present in the year 2014 expect for station F and more numerous in 2015 without a clear pattern but with highest abundance at station I (between cages). *Galathowenia oculata* is present only at the 2 farthest stations (A and B) for all years but more abundant in 2013. *Chaetozone setosa* was more common at stations A and B in 2014 and 2015, with only a few individuals found at the other stations in 2015.

Parougia negridentata was present in all stations, expect those closest to the cages, every sampling time, but more abundant in 2013 and 2014. *Pectinaria sp (koreni)* was found mainly in 2014 and closest to the cages. *Scoloplos armiger* was present mainly in 2015 at all stations but was more numerous at stations B and C. *Sternaspis scutata/islandica* was only found at station A in all years. *Nephtys sp (caeca)* was present mainly in 2015 and more common at the stations farther from the aquaculture cages. *Malacoceros fuliginosus* was present almost exclusively in 2013 at all stations expect A and F.

Other Polychaeta were present in lower numbers. Between these 2 different patterns could be distinguished, species such as *Aricidea suecica, Euchone sp, Goniada maculata* and *Prionospio steenstrupi* were present only or mainly at station A. Species such as *Ophelina acuminata, Scalibregma inflatum* and *Syllis sp* show no clear pattern of distribution.

The other class worth mentioning is the one of bivalves. 5 taxa with 2 most abundant species; *Ennucula tenuis* and *Thyasira flexuosa*, both were present all the 3 years but the first was mainly found in 2015 the second mainly in 2013. All bivalves show a general trend with highest abundance far away from the cages and few individuals or total absence at stations D, E and F.

Abundance trends for *Capitella capitata*, other Polychaeta worms and bivalves for the 3 sampling years can be found in figures 6-8.

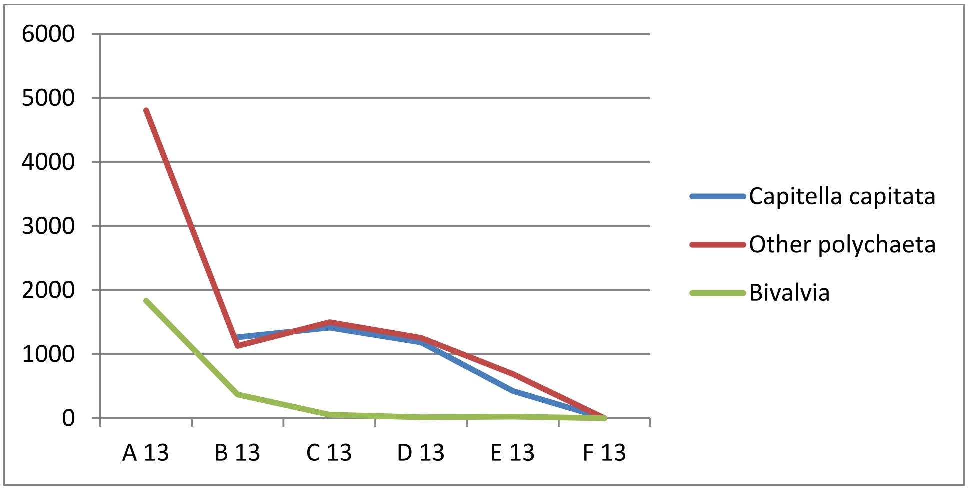

Figure 6. Abundance trends for 3 main taxa in 2013 sampling.

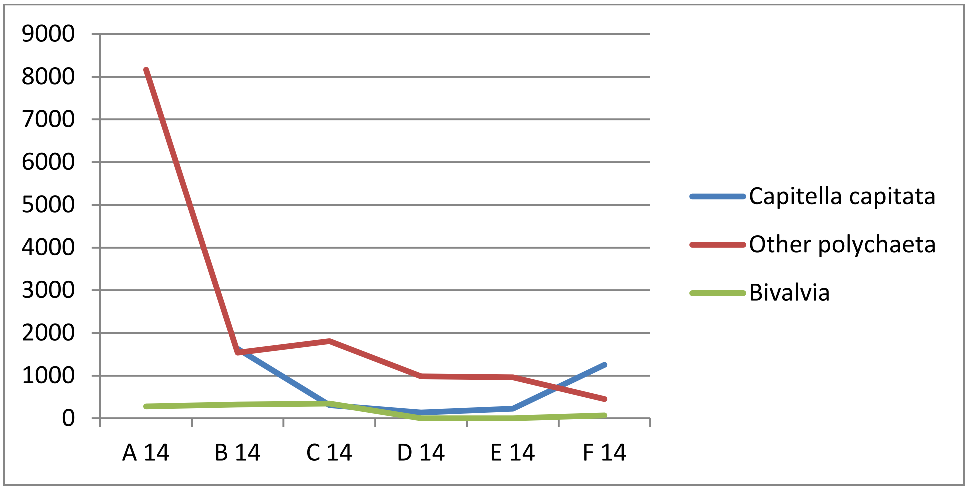

Figure 7. Abundance trends for 3 main taxa in 2014 sampling.

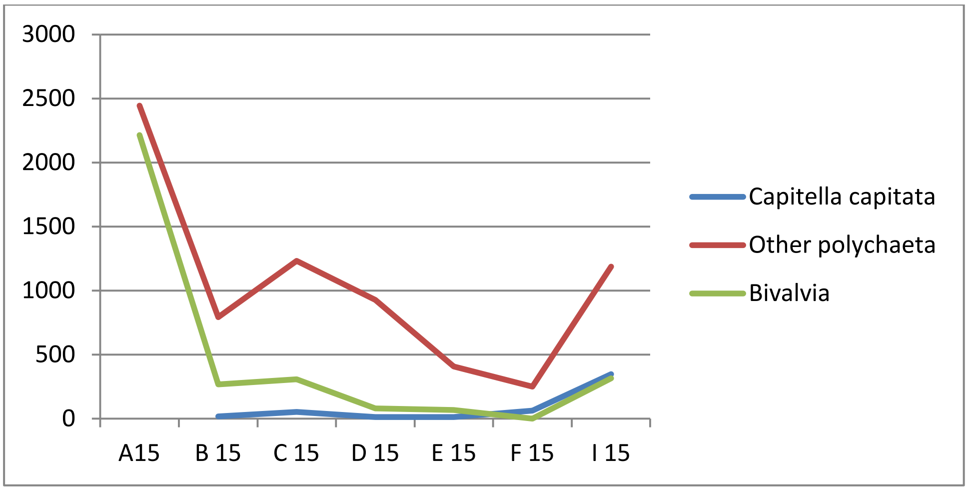

Figure 8. Abundance trends for 3 main taxa in 2015 sampling.

Discussions

Monitoring in Hlaðseyri was conducted at 3 sequential times on 6 stations at varying distance from the aquaculture cages in order to appreciate the trends impose on the benthic community by the fish farming.

The trend for each year shows a decrease in taxa numbers and diversity from the stations farther from the cages to the ones closer to the cages. Fewer taxa were also associated with an increased presence of the indicator species *Capitella capitata* indicating higher accumulation of organic matter in proximity to the cages. The decrease in number of individuals in proximity to the cages, which was also observed for *Capitella capitata,* suggests that a critical level has been reached. The extreme case was station F in the year 2013 (time of full operation) where sediment was deprived of macrofauna.

The smell evaluation (table 1) also points to the over accumulation of organic matter in proximity to the cages, the magnitude of this accumulation could be better assessed by chemical analysis.

The significant drop in polychaetes abundance between st. A and st. B in 2013 and 2014 (figure 4 and 5) may indicate that the border line for the area that is significantly affected by the aquaculture practise is positioned between these two stations. Absence of resistant species *Capitella capitata* and presence of sensitive species as *Aricidea suecica* and *Prionospio steenstrupi* at station A, for all 3 years, could support this assumption (Rygg 2002, Dean 2008).

The drop in the diversity index between 2013 and 2014 for stations A and B is likely to be due to the increased amount of organic matter deposited during that year of farming. It is more difficult to make assumptions on the increase of the same index (between same years) for other stations.

Both the number of taxa and diversity index´s values became more similar across stations in 2015 probably as the source of disturbance was removed.

Diversity increases from the year 2013 (full operation) to 2015 (after 9 months of no farming). This can be seen as a positive trend. However, comparison with the surveys made in 2002, 2009 and 2012 show a different composition of the benthic community. In 2015 polychaetes of families such as Sabellidae, Polynoidae, Spionidae were absent and others of the family Owenidae and bivalves were in reduced number (Asle Guneriussen & Rune Palerud 2003, Böðvar Þórisson *et al*. 2012, Ólafsdóttir S.H. 2015). Species present in the survey of 2015 are indeed known to tolerate a certain degree of organic accumulation (Rygg 2002, Dean 2008). It is therefore difficult to estimate the extent of the recovery for the sediments under the aquaculture cages.

Station I was sampled only in year 2015 but we can assume its status had been similar to F in year 2013. After this 9 month period of no farming still the station shows low diversity.

Based on the results from this study it can be concluded that a recovery period of 9 months has been insufficient for the aquaculture area in Hlaðseyri to recover from the effects of aquaculture cages.

Thanks

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References

Asle Guneriussen and Rune Palerud (2003). Umhverfiskannanir í fjórum fjörðum á Íslandi 2002 með tilliti til væntanlegra uppbyggingu fiskeldis. Akvaplan Niva.

Brage R. and Thélin I. (1993). Klassifisering av miljökvalitet I fjorder og kystfarvann. Virkningar av organiske stoffer. Statens forurensingstilsyn (SFT).

Böðvar Þórisson, Cristian Gallo, Eva Dögg Jóhannesdóttir og Þorleifur Eiríksson (2012). Botndýraathuganir í Arnar- og Patreksfirði vegna fyrirhugaðs fiskeldis Fjarðalax. Unnið fyrir Fjarðalax. Náttúrustofa Vestfjarða, NV nr. 07-12.

Clarke K.R. and Warwick R.M. (2001). Change in marine communities: An approach to statical analysis and interpretation. Primer-E Ltd.

Dean H. (2008). The use of polychaetes (Annelida) as indicator species of marine pollution: a review. Revista de Biología Tropical, Vol 56: 11-38.

Grey J.S, A.D. McIntyre og Stirn J. (1992). Manual of methods inaquatic enviroment research. Biological assessment of marine pollution – with particular reference to benthos. Part 11. FAO. Fisheries technical paper 324: pag.49.

Karakassis I., Hatziyanni E., Tsapakis M., Plaiti W. (1999). Benthic recovery following cessation of fish farming: a series of successes and catastrophes. Marine Ecolog, Vol 184: 205-218

Kutti T., Hansen P.K., Ervik A., Hoisæter T. and Johanessen P. (2007). Effect of organic effluents from a salmon farm on a fjord system. II. Temporar and spatial patterns in infauna community composition. Aquaculture, Vol 262: 355-366.

Johannessen P., Botnen H.B., Tvedten O.F. (1994). Macrobenthos: before, during and after a fish farm. Aquaculture and Fisheries Management Vol 25: 55-66

Ólafsdóttir S. H. (2015). Benthic communities in Tálknafjörður and Patreksfjörður. Hafrannsóknir nr.179. Hafrannsóknastofnun, Reykjavík.

Pearson TH., Rosenberg R. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Annu Rev 16: 229-311.

Rygg B. (2002). Indicator Species Index for Assessing Benthic Ecological Quality in Marine Waters of Norway. NIVA Report SNO 45-48-2002.

APPENDIX 1

Table 4. Benthic community in Hlaðseyri 2013-2014-2015 in individuals/ m2.

Taxa	A 13	A 14	A 15	B 13	B 14	B 15	C 13	C 14	C 15	D 13	D 14	D 15	E 13	E 14	E 15	F 13	F 14	F 15	I 15
Anelida Polychaeta																			
Apistobranchus tullbergi												13							
Aricidea suecica	67	27	147																
Capitella capitata				1267	1627	17	1413	312	53	1187	137	13	427	224	13		1257	64	348
Chaetozone setosa	57	733	227	13	53	13			13			4			13			13	
Cirratulus cirratus						13													
Cossura longocirrata	2173	6547	672	587	16	52	27	267	84	13	27	133	4	53					
Eteone longa	27	133	627		17	32		213	533		4	533		88	267			97	1173
Euchone sp	8	8	28																
Galathowenia oculata	1893	467	44		32	13													
Goniada maculata	53																		
Hesionidae							27												
Laonice sp																		13	
Lumbrineris sp															13				
Malacoceros fuliginosus				53			4			27		13	16						
Mediomastus fragilis				27			13			13	27	13							
Melinna cristata	13																		
Microphthalmus aberrans	133	97	173	117	1227	373	1427	1253	267	1147	827	53	613	72	17		427	16	
Nephtys caeca	27	27	133																
Nephtys sp		27				27			67			27			17			4	
Ophelina acuminata	27					12			8			8			13			13	
Parougia nigridentata	12	57	8	267	187	4	4	24	8	53	16	27	53		27			13	
Pectinaria koreni						13			27			13							
Pectinaria sp				13							27			693			27		
Polynoidae					8														
Prionospio steenstrupi	36	12	187			13			13			13							
Scalibregma inflatum				27		27			13			67			13			13	
Scoloplos armiger	13	27	27			173			133			8			27			67	13
Spio sp						27													
Sternaspis scutata/islandica	267	4	173																
Syllis sp				27				53	67		53		4	53					
Mollusca Bivalvia																			
Abra nitida	427			53															
Ennucula tenuis	128	124	1733	93	267	267		293	253			67			53			67	
Mytilus edulis	147			92															
Nuculana sp	187	147	267									13			13				
Thyasira flexuosa	947	8	213	133	53		53	53	53	13			27						
Arthropoda																			
Leucon nasica		27										4							
Euphausiacea					27														
Ostracoda	93	77	133	133			67												
Copepoda	52																		
Priapulus caudatus					53							13							
Nematoda	72	467	573	747	177	1533	28	1173	587	147	133	187	53	0	67		0	17	213

APPENDIX 2

Table 5. Benthic community (alphabethical order) for Hlaðseyri 2013-2014-2015 in individuals/ m2 Used for Primer 6.

Taxa	A 13	A 14	A 15	B 13	B 14	B 15	C 13	C 14	C 15	D 13	D 14	D 15	E 13	E 14	E 15	F 14	F 15	I 15
Abra nitida	427	0	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apistobranchus tullbergi	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Aricidea suecica	67	27	147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capitella capitata	0	0	0	1267	1627	17	1413	312	53	1187	137	13	427	224	13	1257	64	348
Chaetozone setosa	57	733	227	13	53	13	0	0	13	0	0	4	0	0	13	0	13	0
Cirratulus cirratus	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cossura longocirrata	2173	6547	672	587	16	52	27	267	84	13	27	133	4	53	0	0	0	0
Ennucula tenuis	128	124	1733	93	267	267	0	293	253	0	0	67	0	0	53	0	67	0
Eteone longa	27	133	627	0	17	32	0	213	533	0	4	533	0	88	267	0	97	1173
Euchone sp	8	8	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphausiacea	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0
Galathowenia oculata	1893	467	44	0	32	13	0	0	0	0	0	0	0	0	0	0	0	0
Goniada maculata	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0
Laonice sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0
Leucon nasica	0	27	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Lumbrineris sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0
Malacoceros fuliginosus	0	0	0	53	0	0	4	0	0	27	0	13	16	0	0	0	0	0
Mediomastus fragilis	0	0	0	27	0	0	13	0	0	13	27	13	0	0	0	0	0	0
Melinna cristata	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microphthalmus aberrans	133	97	173	117	1227	373	1427	1253	267	1147	827	53	613	72	17	427	16	0
Nephtys caeca	27	54	133	0	0	27	0	0	67	0	0	27	0	0	17	0	4	0
Nuculana sp	187	147	267	0	0	0	0	0	0	0	0	13	0	0	13	0	0	0
Ophelina acuminata	27	0	0	0	0	12	0	0	8	0	0	8	0	0	13	0	13	0
Ostracoda	93	77	133	133	0	0	67	0	0	0	0	0	0	0	0	0	0	0
Parougia nigridentata	12	57	8	267	187	4	4	24	8	53	16	27	53	0	27	0	13	0
Pectinaria koreni	0	0	0	13	0	13	0	0	27	0	27	13	0	693	0	27	0	0
Polynoidae	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Priapulus caudatus	0	0	0	0	53	0	0	0	0	0	0	13	0	0	0	0	0	0
Prionospio steenstrupi	36	12	187	0	0	13	0	0	13	0	0	13	0	0	0	0	0	0
Scalibregma inflatum	0	0	0	27	0	27	0	0	13	0	0	67	0	0	13	0	13	0
Scoloplos armiger	13	27	27	0	0	173	0	0	133	0	0	8	0	0	27	0	67	13
Spio sp	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0
Sternaspis scutata/islandica	267	4	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllis sp	0	0	0	27	0	0	0	53	67	0	53	0	4	53	0	0	0	0
Thyasira flexuosa	947	8	213	133	53	0	53	53	53	13	0	0	27	0	0	0	0	0