A century of monitoring station Prince 6 in the St. Croix River estuary of Passamaquoddy Bay

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A collaborative project involving Fisheries and Oceans Canada, Environment Canada, Passamaquoddy people, and Bay of Fundy Ecosystem Partnership

BoFEP

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June 8, Oceans Day, 2015

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Introduction:

The purpose of this project is to improve understanding of the diversity, concentration, and phenology of plankton populations in St. Croix Estuary, an integral part of Passamaquoddy Bay and of the Quoddy region.

Passamaquoddy Bay in southwest New Brunswick is known to be a productive area with fisheries such as scallop (***Placopecten magellanicus***), American lobster; (***Homarus americanus***), clam (***Mya arenaria***), crab (***Cancer***), sea weed (***Laminaria, Fucus***, and ***Palmaria palmate***), sea urchin (***Strongylocentrotus droebachiensis***), herring (***Clupea harengus***), and groundfish such as cod (***Gadus morhua***), haddock; (***Melanogrammus aeglefinus***), pollock (***Pollachius virens***),and flounder (***Hippoglossus hippoglossus***). This bay additionally provides spawning areas for a large number of fish species such as cod, haddock and pollock. Harbour porpoise (***Phocoena phocoena***) dolphin (***Delphinus***) and minke whale (***Balaenoptera acutorostrata***) are often sighted in the region. Outside Passamaquoddy Bay, in the Bay of Fundy is an important bird area where whales such as fin (***Balaenoptera physalus***), right (***Eubalaena glacialis***) and sperm (***Physeter catadon***) have been found (Chang et al, 2005; anon, 1982). Two of the largest fish in the Atlantic: the great white shark (***Carcharodon carcharias***) and the basking shark (***Cetorhinus maximus***) have also been found here.

Ecosystem monitoring in the Bay of Fundy began in 1916. **Hydrographic** (sea surface temperature, salinity, tidal state, water colour), **weather** (air temperature, wind, fog), and **biological** (zooplankton) observations were made weekly at station Prince 6 in the St Croix River estuary from 1916 to 1944 and monthly thereafter. The depth of this monitoring site is about thirty meters and it is located in the middle of the St. Croix River between The St. Andrews Biological Station and Robbinston, Maine as shown in figure 1. Unfortunately, zooplankton catch data between the years 1916 to 1936 and from after 1970 has been lost.

Zooplankton populations studied in Passamaquoddy Bay in earlier years show the area to be rich in species and abundance indicating a productive region. Willey (1915) sampled the bay in July and August of 1912. McMurrich (1917) described the composition of plankton in winter around St Andrews. Legaré and McClellan (1960) sampled and described the zooplankton in great detail at seven stations within and seven stations outside of Passamaquoddy Bay forty three-times at regular intervals between January 1957 and December 1958. A detailed comparison of two stations; one outside of Passamaquoddy Bay and station Prince 6 in the estuary was done and Legaré (1961) discussed the phenology of several zooplankton taxa using catch data from 1937 to 1959, a time series of twenty-three years.

Differences of catch composition are, according to Willey (1915) "… both qualitative and quantitative and are as noteworthy when comparing different localities at the same time, as when comparing different seasons at one and the same station. Under these circumstances, in order to secure complete and reliable data respecting the periodic fluctuations of the Plankton, it is necessary to institute continuous series of observations at a given locality throughout at least one entire year, and better still through several successive years, after the manner adopted in recording meteorological conditions, with which the various planktological conditions are directly and intimately correlated."

This report contains a one hundred year series of surface temperature and an eighty year series of surface salinity combined with a timeline of hurricanes that may have affected the St. Croix watershed.

The diversity, density and phenology of zooplankton from 2011 to 2015 and of icthyoplankton from 1937 to 1970 are presented and compared using the same plankton net size and mesh.

The vertical tow series is presented first with time versus logarithmic density plots as well as composite day of year versus logarithmic density plots. Presence absence is presented by month for the years 2012 to 2014 and as an overview taking into consideration all of the catch data from August of 2011 through to February of 2015. The two subsurface tow series are presented with time versus logarithmic density plots only. There are comparisons made between the fish larvae from both historic and contemporary series.

Research and good luck yielded preserved samples from between 1929 and 1972 from the Canadian Museum of Nature in Gatineau, Quebec. The preserved samples will be sorted and counted in order to validate the 1937 to 1970 invertebrate catch data and to extend the series by ten years. The results of these studies and of validated hydrographic data from below surface will be reported in planned data and technical publications.

There is a wealth of data, yet it remains largely unstudied and unavailable to the public and to decision makers. This represents a truly unique opportunity; time-series studies of this magnitude are rare, yet they are crucial to identification of long-term ecological trends and regime shifts as well as to the development of adaptive management strategies.

METHODS:

Historical samples - field

Historical sampling material and methods were taken from J.E. Henri Legaré, 1961. The Zooplankton of the Passamaquoddy Region.

“Plankton collections since 1913 have been made by the staff of the FRB of Canada’s Biological Station, St. Andrews, NB in the Passamaquoddy Region of New Brunswick and Maine. Prince 6 is located opposite the Biological Station, midway in the St. Croix River estuary.” (Legaré, 1961)

The latitude and longitude of Prince 6 is given as 45 degrees 4 minutes 49 seconds N, 67 degrees 5 minutes 53 seconds W (Vachon, 1918).

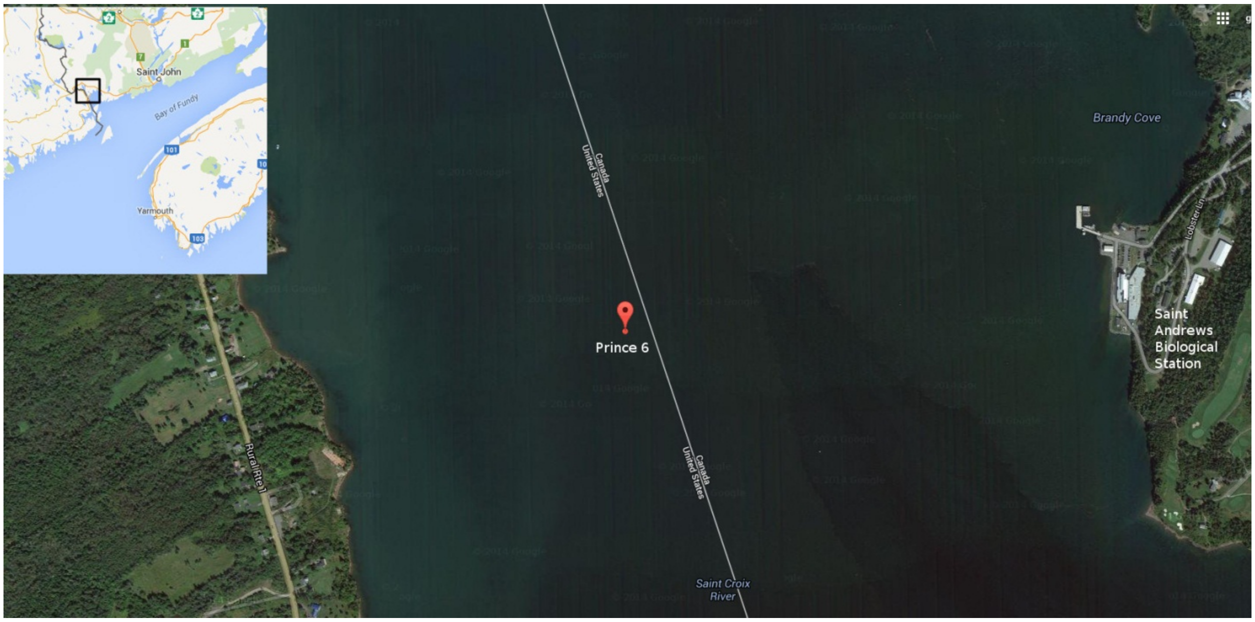


Figure 1. Station Prince 6 located opposite the Biological Station midway in the St. Croix River estuary of Passamaquoddy Bay.

Hydrographic sampling

“Surface water was collected in a bucket and hauled up” (Vachon, 1918).

“I took the temperature of the surface from the water in the bucket by means of a Centigrade thermometer graduated in tenths of a degree and whose accuracy I had verified beforehand.” (Vachon, 1918)

Water colour was documented. Weather observations such as air temperature, extent of cloud cover, wind speed and/or direction as well as sea surface state were also made. A water sample was taken from the bucket for later salinity determination.

“The samples of water collected must afterwards be analyzed. In such analysis the halogens are titrated with silver nitrate and the results given as grams of chlorine per thousand grams of water…Mohr’s method is used for the determination of chlorine.” (Vachon, 1918)

“For accurate seawater analysis, a special burette is desirable: the ordinary burette is too wide and too short for the required accuracy. The reading should be certain to a hundredth part of a c.c., which is difficult with the ordinary burette. Besides, the ‘drainage error’ is greater than in the special one, the upper part of which is an ungraduated bulb that terminates in a fine jet. The lower part of this burette is a narrow tube graduated in hundredths of a c.c. At the present time it is most difficult, not to say impossible, to obtain one of these special burettes. Dr. Huntsman was able to get one from Dr. Mathews, of the Plymouth Marine Biological Laboratory, England, but, most unfortunately, it was broken when it reached me. Two others, made to order by the Eimer and Amend Company also arrived in a broken state. We hope to be fully equipped with all the special apparatus in the near future.” (Vachon, 1918).

Zooplankton samples – from Legaré, 1961:

There are three different plankton tows performed at each station visit: A vertical haul using a twelve inch (30.45cm diameter) number five net [280 micron mesh] from thirty m to the surface, a horizontal fifteen minute haul using a twelve inch net of number five mesh [280 microns] at a depth of five to seven m, and a horizontal fifteen minute haul using a one m closing net of number zero mesh [575 micron]at a depth of eighteen to twenty-three m.

Samples were preserved aboard ship in a five percent solution of formaldehyde in seawater (Clayton Dickson, personal communication).

Historical samples- laboratory

"Qualitative and quantitative analyses were made of the zooplankton. Fish larvae were removed and preserved in five percent formaldehyde. Jellies were also removed and their displaced volume was taken. The displaced volumes of the remainder were measured and recorded. Identification was carried out to species in most cases. Large animals were counted separately while numbers of copepods, larvae, and eggs were calculated from samples." (Legaré, 1961)

As of 1959 there were one thousand three hundred sixty-four plankton samples analyzed from station Prince 6. Many other tows had been lost or destroyed through the years but the great majority of those available were in an excellent state of preservation (Legaré, 1961).

Contemporary samples – field

In the most recent series, samples have been collected monthly since August 2011 and, to date, there have been about one thousand eight hundred thirty tows analyzed from this monitoring station.

Hydrographic sampling

Standard oceanographic observations, including Secchi depth and water colour, were made at Prince 6. Surface temperature and salinity were sampled as in the past, from a bucket of surface water collected over the side of the boat as shown in figure 2 (Vachon, 1918). Weather observations such as atmospheric pressure, air temperature, extent of cloud cover, wind speed and direction, as well as sea state were also made and recorded. A calibrated Seabird® 25 CTD profiler was used to measure the conductivity, temperature, depth, light, oxygen, turbidity, and fluorescence, [add sensors?] A weight was attached to the bottom of the CTD profiler, which was put over the side, switched on, and lowered into the water and allowed to equilibrate at the surface for three minutes. It was then lowered to within a meter of bottom at a rate not exceeding 45 meters per minute.

Information from below the surface will be presented in planned data and technical reports that will refer to this publication.

Figure 2. Hydrographic monitoring at station Prince 6. Clockwise from the upper left; Biological Station in background, surface salinity sample, collecting surface water, carrying Secchi disc across deck and CTD profiler deployment preparation.

Zooplankton samples

Zooplankton samples were collected at Prince 6 using three different tows: A ten minute subsurface tow with a coarse mesh net of the same diameter that was used in the past. A ten minute subsurface tow and a vertical tow were done with a seventy-five cm diameter plankton net with a two hundred micron mesh. This is a much larger net than was used in the past and the mesh is bit finer.

For the **vertical tow**, a 75cm 200 micron net with a three point bridle shown in figure 3 was equipped with a depth logger [2011-2013, Vemco® temperature/depth recorder; 2014 RBR® pressure logger] and a hydrographic weight was attached to the cod end. The net was slowly lowered to near bottom and then retrieved at a rate of 1 to 2 meters per second. The net was then rinsed to ensure that the catch was fully contained within the cod end. The cod end was rinsed and the contents were swirled to allow the excess water to drain through the screen. The remaining sample was then poured into a labeled 250 ml jar with 12.5 ml of formaldehyde. If the catch was too large for the sample jar or the cod end, the end of the net and cod end were rinsed into a large container and large jellies were counted, measured, and discarded. Larger containers were used when necessary.

Figure 3. Vertical plankton tow at station Prince 6. Clockwise from upper left: Vertical tow deployment, vertical tow recovery and zooplankton catch in cod end of net.

For the **fine mesh subsurface tow** a General Oceanics® flow meter was tied, off-center, across the mouth of a 75cm 200 micron net equipped with a depth logger [2011-2013, Vemco® temperature/depth recorder; 2014 RBR® pressure logger]. The weight was removed from the cod end and a fin-shaped net depressor on a 2 m rope was attached where the cable meets the net bridle. The flow meter reading was recorded and the net deployed with forty-five meters of cable and towed for 10 minutes below the surface. The starting time, position, and sounding were recorded. Position and depth information were taken from instrumentation aboard the bridge of the sampling platform, ***Viola M. Davidson***. After 10 minutes of towing the end of tow position was recorded and the net retrieved. The flow meter was read and the number recorded. The net was then rinsed to contain the entire catch in the cod end and poured into a labelled 500ml jar with 25ml of formaldehyde. If the catch was too large for the sample jar or the cod end, the end of the net and cod end were rinsed into a large container and large jellies were counted, measured, and discarded. Larger containers were used when necessary.

For the **coarse mesh subsurface tow**, a one m number zero net (575 micron) with a 3 point bridle was equipped with a depth logger [2011-2013, Vemco® temperature/depth recorder; 2014 RBR® pressure logger]. A General Oceanics® flow meter was tied, off-center, across the mouth of the net. The net depressor on a two m rope and net bridle were then attached to the tow cable with a shackle. The flow meter reading was recorded and the net deployed with forty-five m of cable. The start time, position, and depth were all recorded. After approximately one minute of towing, the wire angle will have decreased and an additional fifteen meters of cable was payed out for a total of sixty meters. After 10 minutes of towing at approximately 2 knots the ending position was recorded and the net retrieved as shown in figure 4. The flow meter was read and the number recorded. The net was rinsed to ensure that the entire catch was in the cod end and poured into a labelled 500ml jar with 25ml of formaldehyde. If the catch was too large for the sample jar or the cod end, the end of the net and cod end were rinsed into a large container and large jellies were counted, measured, and discarded. Larger containers were used when necessary.

Figure 4. Coarse mesh subsurface plankton tow at station Prince 6. Clockwise from upper left: Upriver view of the St. Croix during ten minute plankton tow, recovery of net full of barnacle nauplius larvae (almost three million) in April of 2015, rinsing the net, and cod end detached from the net.

Contemporary samples – laboratory

Sample jars which contained preserved zooplankton were left to settle for 24 hours in graduated cylinders as shown in figure 5 before volume determination. After determining volume and characterizing sample type, it was analyzed under a dissecting microscope. Taxa other than copepods were identified (Johnson and Allen, 2005), (Newell and Newell, 1963) and counted. Larger animals were counted separately, while numbers of copepods, larvae, eggs, and smaller organisms were calculated from samples examined under a Nikon ™ dissecting microscope using a black petri dish marked with one cm squares. For the purpose of this study, copepods included adult copepods and the much more numerous copepodites.

Fish (most in larval stages) were removed from the samples and kept separately for identification. Fish were identified (Fahay, 1983) and counted under a dissecting microscope.

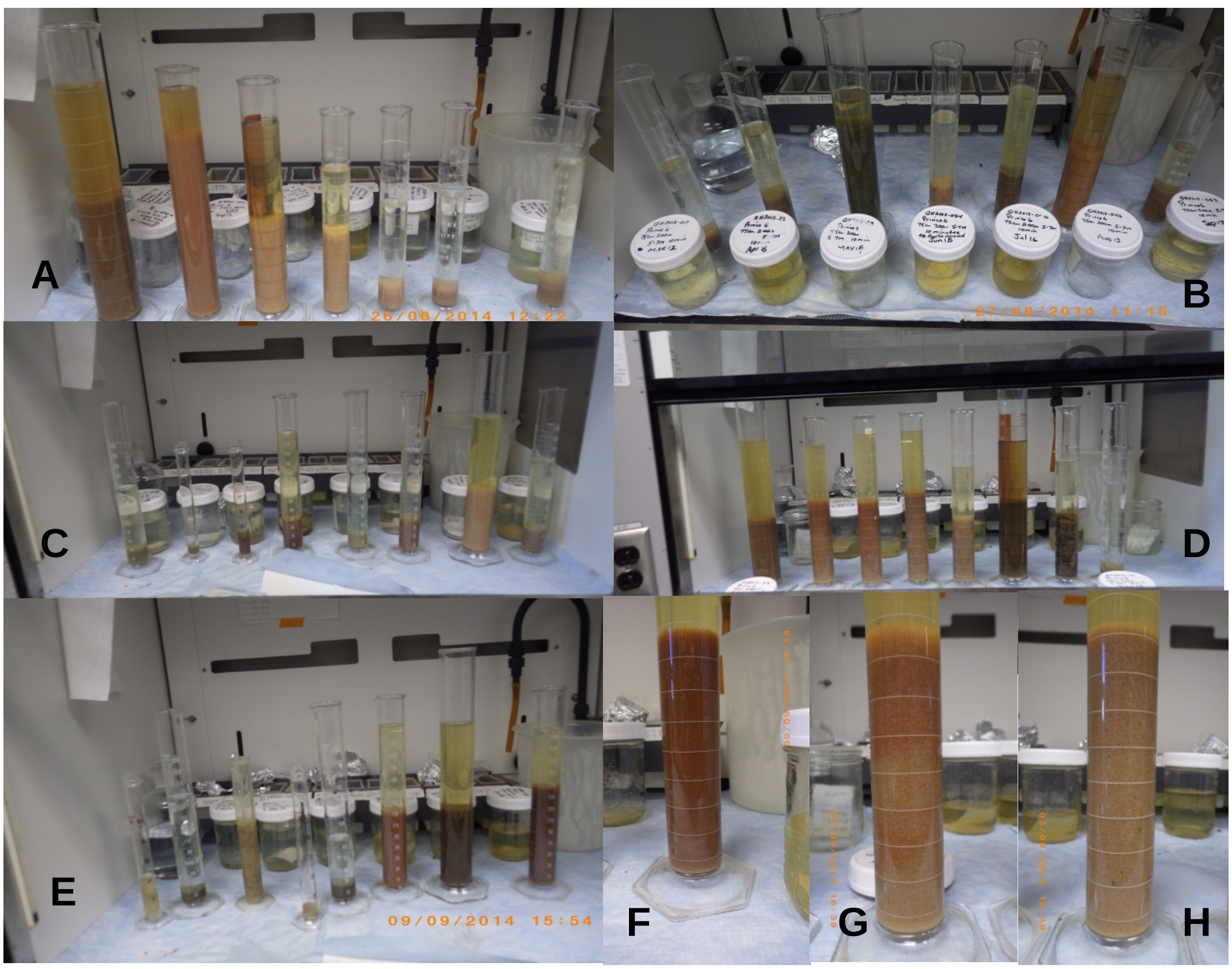


Figure 5. Fine mesh subsurface sample series catch volume determinations: A August 2011 to February 2012, B March 2012 to September 2012, C October 2012 to April 2013, D May 2013 to December 2013, E January 2014 to June 2014, F August of 2011, G August of 2012, H August of 2013.

Once all the samples were analyzed several were picked at random and re-examined several times by the two sorters. A summary of the results of these counts may be found in table 1.

RESULTS AND DISCUSSION

After examination of the depth logger data it was apparent that targeted depth was not achieved on a regular basis for the shallow and deep plankton tows. A solution to this difficulty was found by renaming the plankton tows from deep and shallow to coarse and fine mesh subsurface tows.

Four replicates of calanoid copepod counts were done on four vertical tow samples to compare sorters.

Variation in zooplankton counts by the two sorters

Nov 14, 2012	sorter 1	sorter 2	% difference
1	1875	2200	
2	2275	1750	
3	2550	2425	
4	2500	1950	
average	2300	2081	10.5
standard dev.	307	294	
Jan 16, 2012			
1	13300	10500	
2	17900	17250	
3	33800	17250	
4	25600	22000	
average	22650	16737	35.3
standard dev.	9000	4730	
Nov 21, 2013			
1	31800	35100	
2	49600	34500	
3	50000	32850	
4	42000	26250	
average	43350	32175	34.7
standard dev.	8534	4063	
Jun 12, 2013			
1	67400	34000	
2	62400	66800	
3	84400	85600	
4	43600	86000	
average	64450	68100	5.7
standard dev.	16789	24435	

Table 1. Comparison of zooplankton sorters: Vertical tow catch number of copepods based on samples.

There was, over four trials with four replicates each, a twenty-one percent overall average difference in the counts of calanoid Copepoda between the two sorters.

Hydrographic conditions sea surface temperature

In 1961 Legaré wrote

"At Prince 6 the surface layer has its maximum temperature a month earlier than at the bottom, and the minimum temperatures are reached around mid February at both depths. The water becomes uniform from bottom to surface in March and October (Bailey, 1957)."

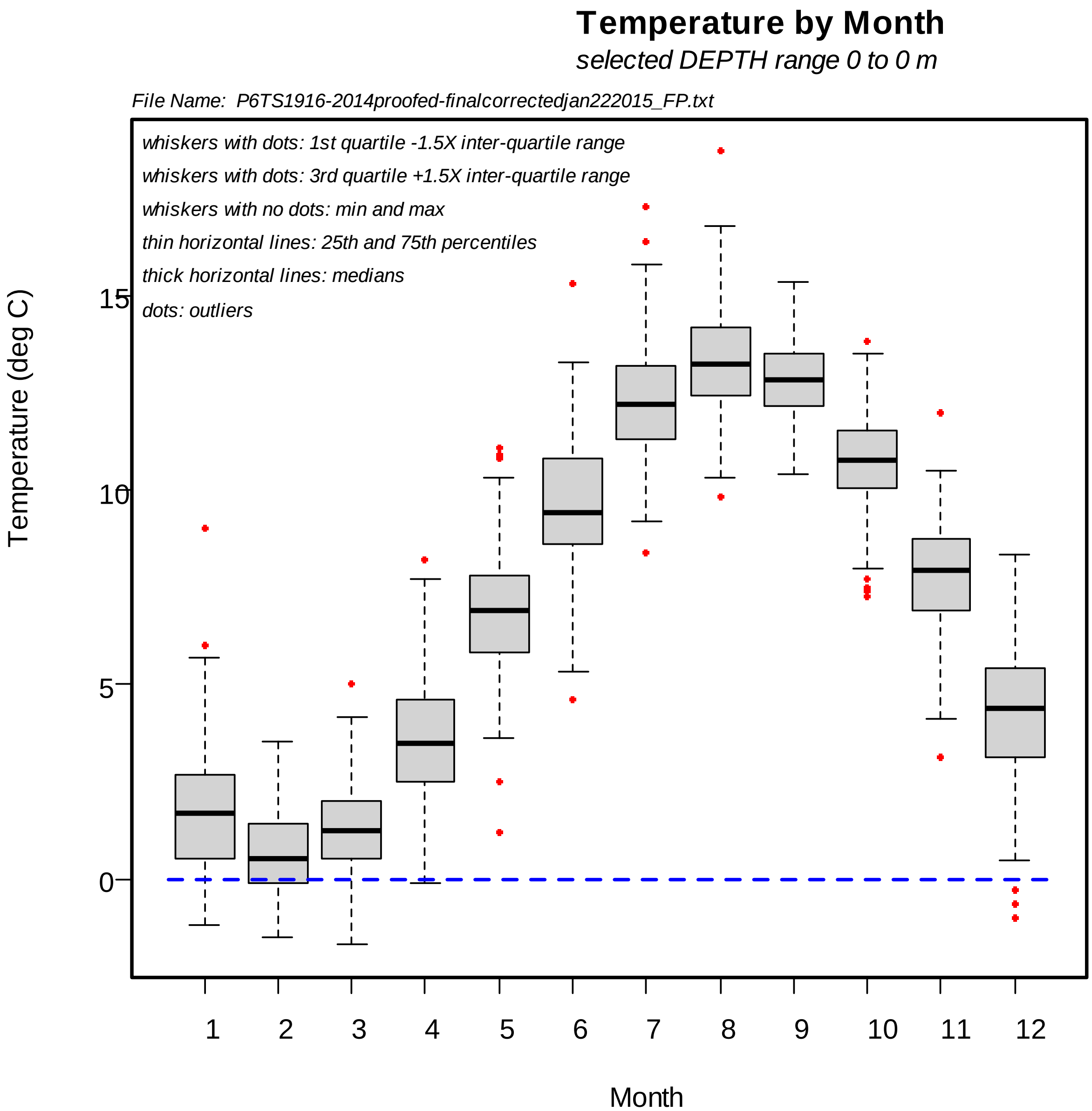


Figure 6. Box and whisker plot of annual temperature variation over the time series of surface temperature at station Prince 6 recorded between November, 1915 and November, 2014.

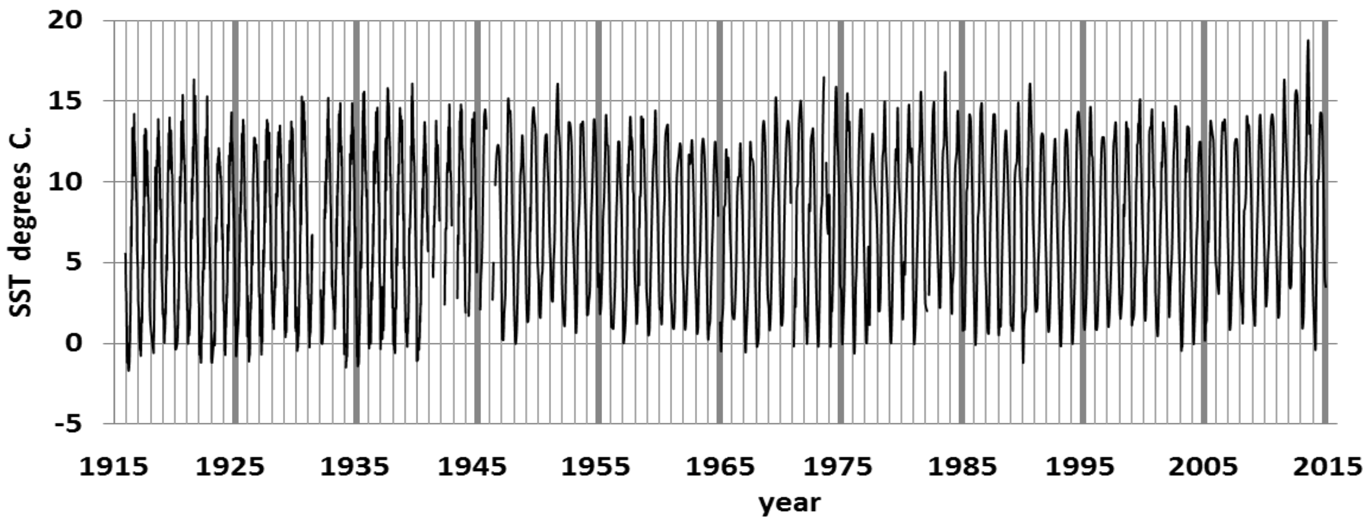


Figure 7. One hundred year time series of sea surface temperature at station Prince 6. There are data gaps resulting from a fire at the Atlantic Biological Station in 1931 and from lack of winter sampling between 1941 and 1945. Sampling rate was weekly from 1916 to 1944 and monthly thereafter.

There was regular annual pattern of warming which started soon after the new year and continued until the fall season when cooling started and then continued until soon after the following new year.

There were differences in maximum temperature as much as four degrees (fall seasons of 1922 and 1924). In the decade 1935-1944 there were eight surface temperature maxima equal or greater than fourteen degrees and in the decade 1955-64 there were only three. There were winters with sea surface temperature cooler than zero degrees in all the decades except two; the twenty years between 1945 and 1964.
The nineteen sixties have noticeable cooler summer surface temperature maxima and there is a noticeable difference in surface temperature minima between the periods of 1915 to 1925 and 2005 to 2015; the earlier period being cooler.

Minimum sea surface temperatures for eight of the twelve months were observed in the first 11 years of the 99 year series. The coldest February was in 1934 and 1939 saw the coldest December. The coldest May and July were in 1977 and 1940 respectively.

Maximum sea surface temperature for September was observed in 1921 and July and August maxima were in 2013.

Hydrographic conditions **sea surface salinity**

In 1961 Legaré wrote

"At Prince 6 the salinity curves are deformed by the excess of fresh waters poured into the bay at the time of the spring runoff (Bailey, 1957)."

"The surface curve has its maximum and minimum at the same time as at the bottom."

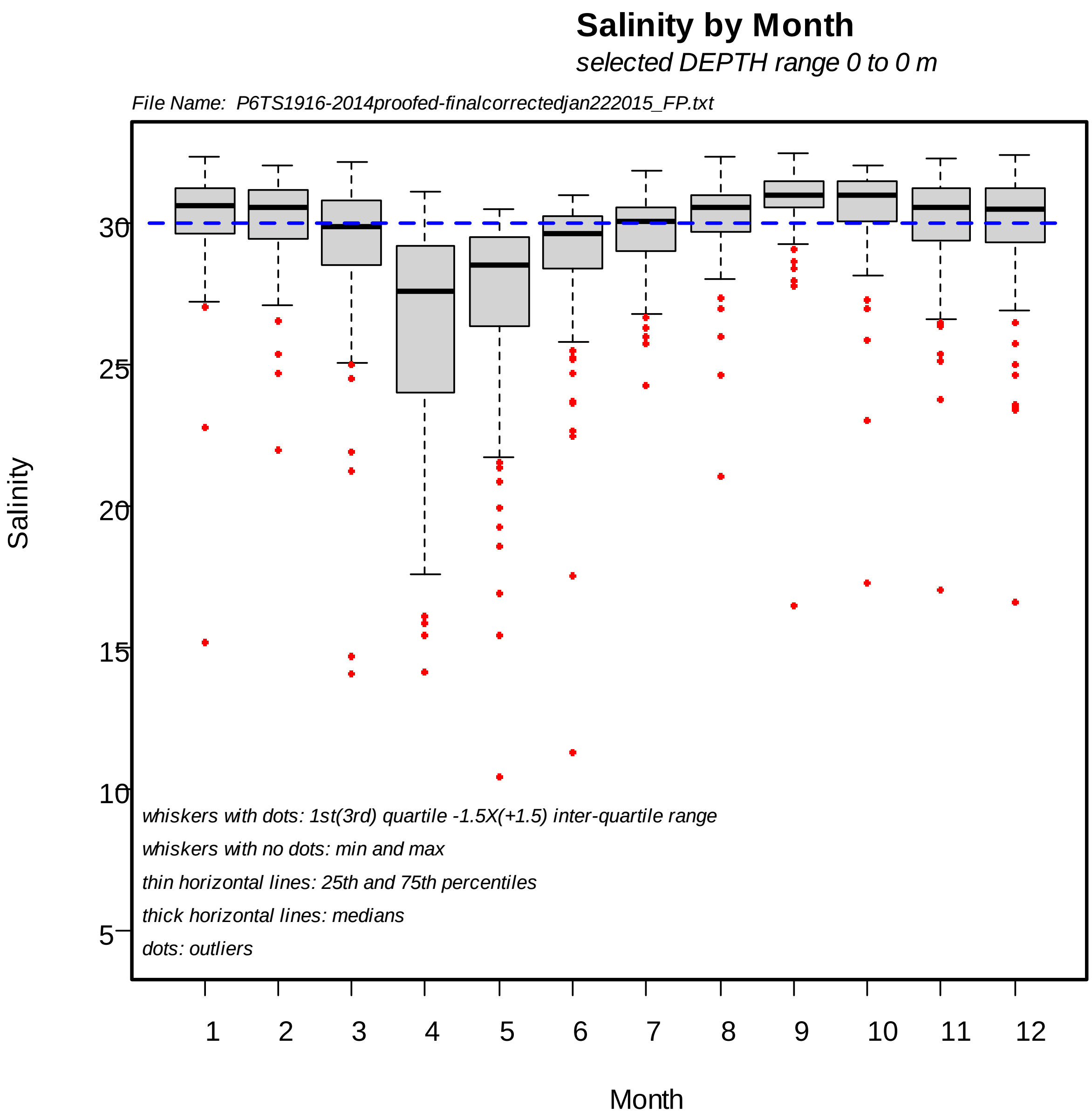


Figure 8. Box and whisker plot of annual salinity variation over the time series of surface salinity at station Prince 6 recorded between November, 1915 and November, 2014.

April and May experience the highest variability and the lowest average salinities over the series. September is the least variable and has the highest salinity. There are no very low salinity outlier data points in the months of February and July but there are in all other months of the year. Some of these may be related to notable past events such as the freshets of December 2010, August of 2013 and December 2014 as seen in figure 17.

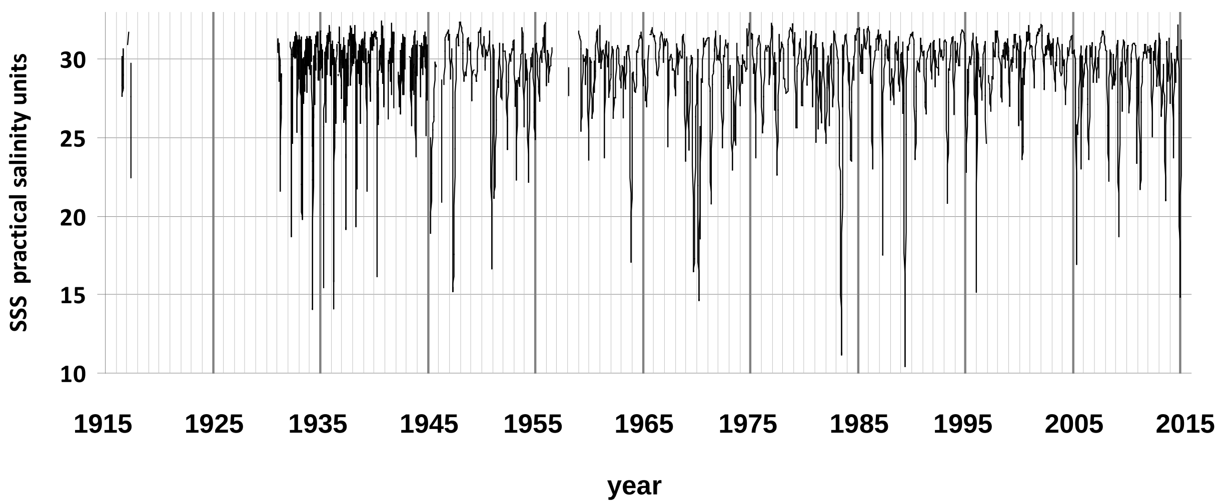


Figure 9. Time series of sea surface salinity at station Prince 6. There are large data gaps resulting in part from a fire at the Atlantic Biological Station in 1931 and possibly the lack of suitable lab equipment. Winter observations are lacking between 1941 and 1945. Sampling rate was weekly from 1916 to 1944 and monthly thereafter. The difference between weekly and monthly monitoring can be seen in the traces of surface salinity in figures 10 and 11.

Sea surface salinity and Atlantic hurricanes time-line back to 1935

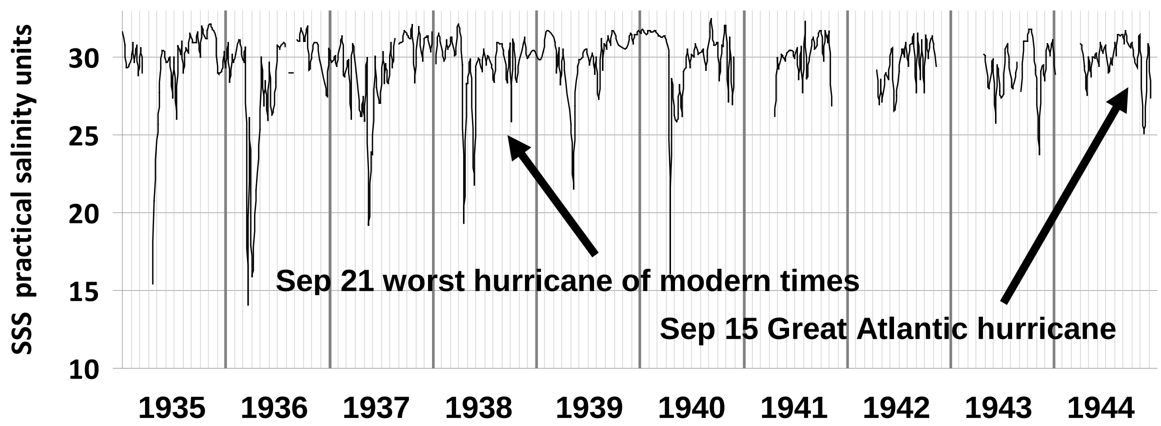


Figure 10. Weekly sea surface salinity between 1935 and 1944 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there were few hurricanes but they were significant. The Great hurricane of September, 1938 was the first hurricane to strike New England since 1869.

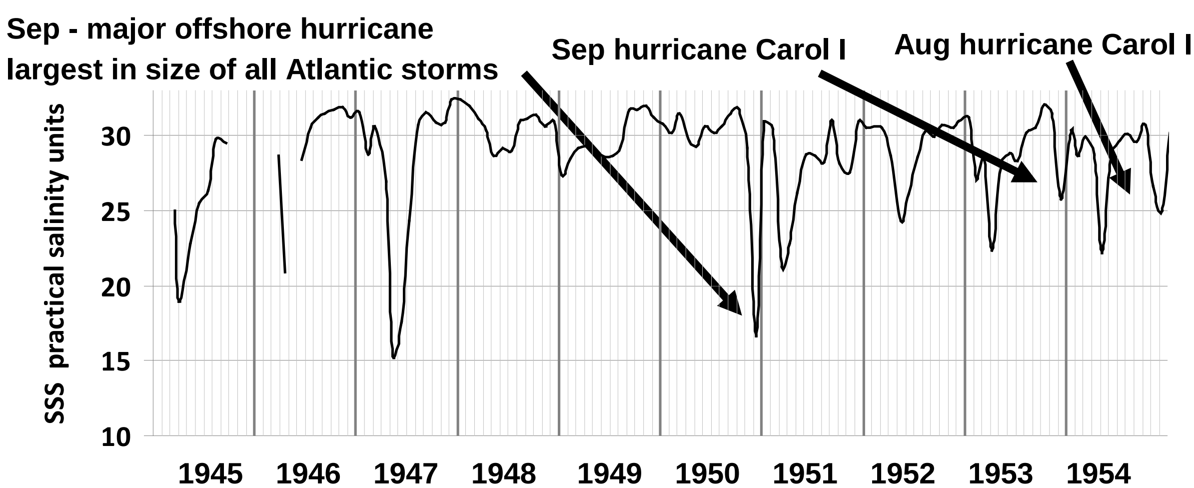


Figure 11. Monthly sea surface salinity between 1945 and 1954 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there was another significant hurricane in 1950 and other hurricanes in two successive years; 1953 and 1954.

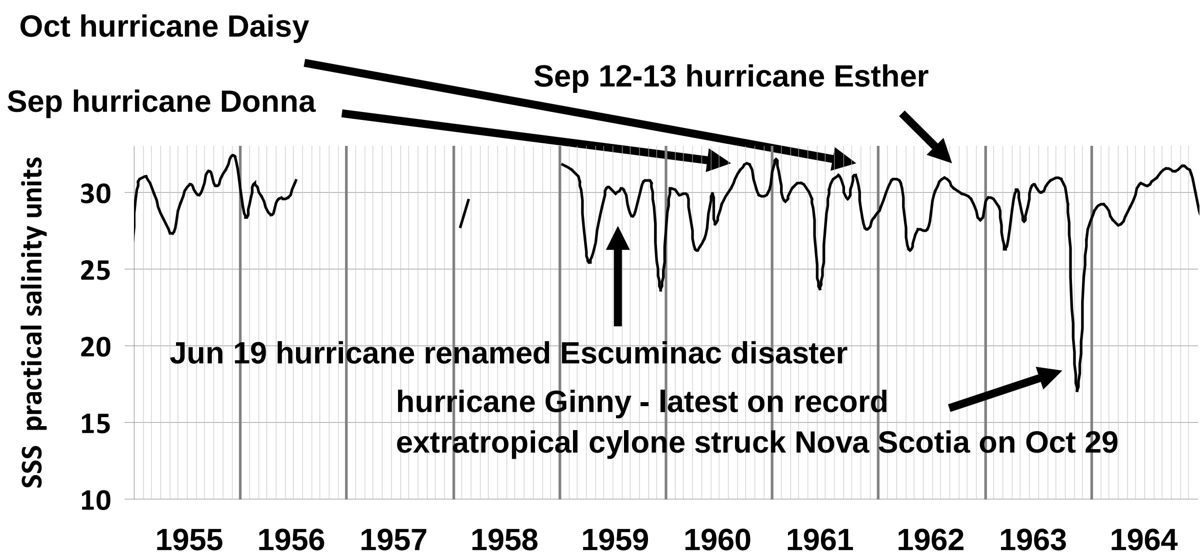


Figure 12. Sea surface salinity between 1955 and 1964 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there was another significant hurricane in 1963 and there were hurricanes in the four previous years.

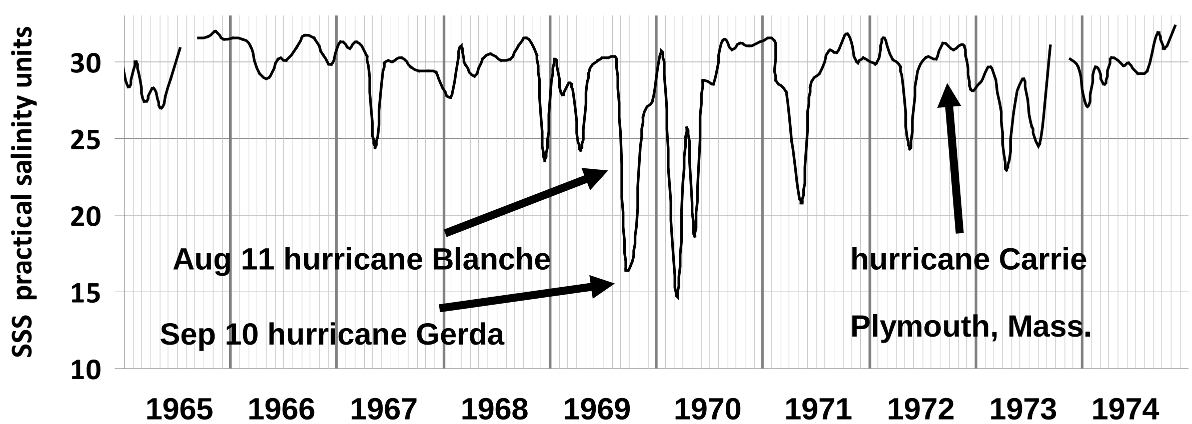


Figure 13. Sea surface salinity between 1965 and 1974 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there was a lot of activity in 1969 with a dozen Atlantic hurricanes. This had not been seen since 1933 and it was a record that stood until 2005.

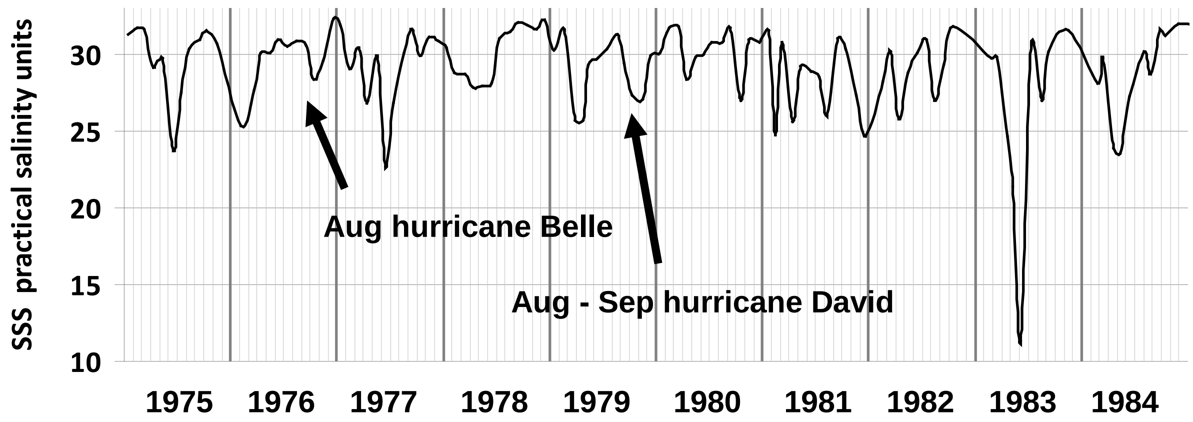


Figure 14. Sea surface salinity between 1975 and 1984 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there two August hurricanes.

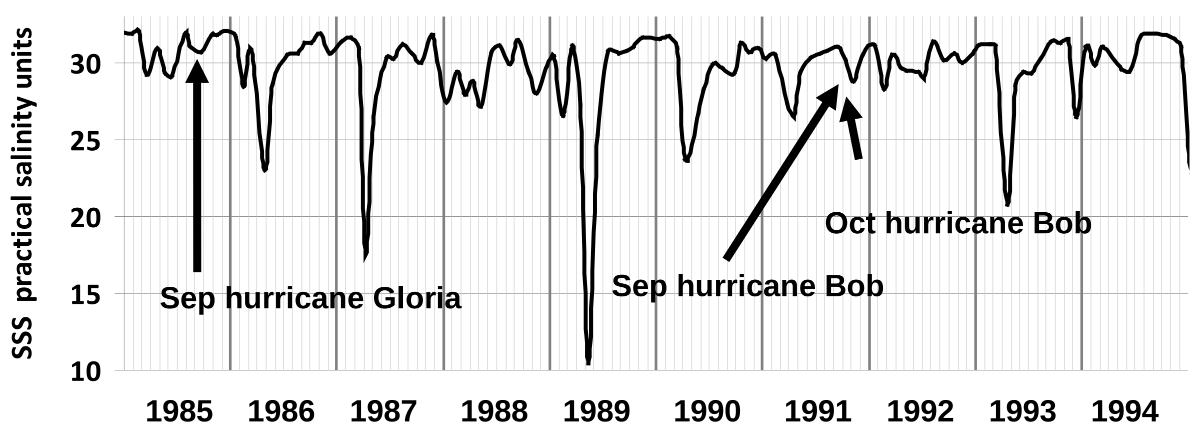


Figure 15. Sea surface salinity between 1985 and 1994 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there were three hurricanes, two in 1991.

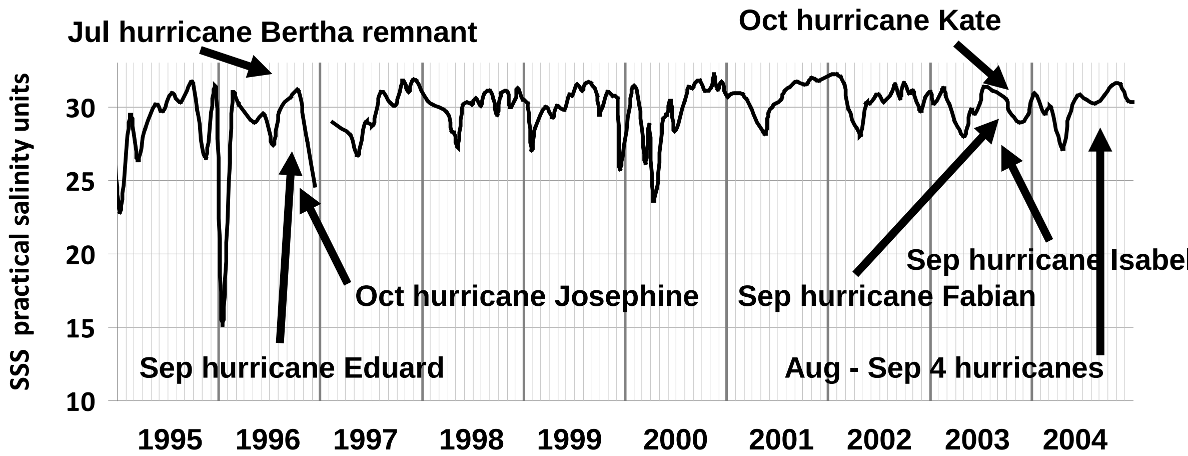


Figure 16. Sea surface salinity between 1995 and 2004 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there were ten hurricanes; three in 1996, three in 2003 and four in 2004.

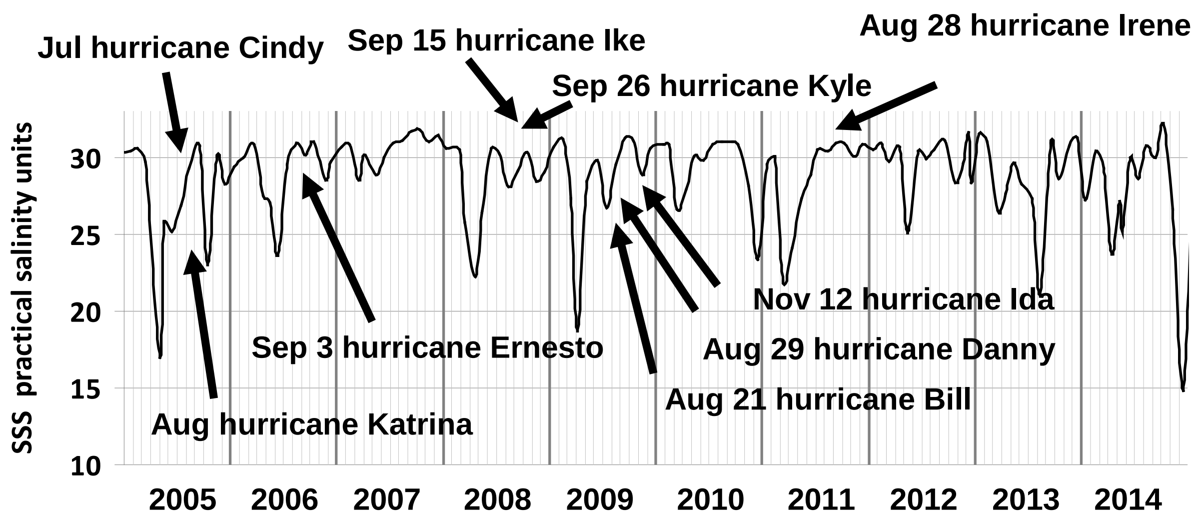


Figure 17. Sea surface salinity between 2005 and 2014 at station Prince 6. Notable hurricanes are indicated with arrows.

During this ten year period there were nine hurricanes; two in 2005, one in 2006, two in 2008 and three in 2009. The most active Atlantic hurricane season in recorded history was in 2005. Twenty-eight tropical and sub-tropical storms formed, fifteen of which became hurricanes. The third most active Atlantic hurricane season on record was 2010; tied with 1887, 1995, 2011 and 2012 hurricane seasons. The activity in the north Atlantic was greater than in the northwest Pacific typhoon season in 2010. This has only happened once before in the year 2005. There were no hurricanes in 2013. The freshening in the fall season of 2010 happened after hurricane Earl passed through in Early September.

Continuous surface salinity monitoring of the station would provide an index for a fine-scale record of rainfall and meltwater in the St. Croix watershed. It would also allow consideration to the variations in water temperature and salinity over a tidal cycle.

Biological conditions   diversity and life history

The table below defines the taxonomic level of each group used in this report using up-to-date information from The World Register of Marine Species (WoRMS).

Table 2. Description of taxa identified from station Prince 6 plankton tows between August 2011 and February 2015.

Level Taxon	Description
Order Calanoida	Superorder Gymnoplea<Infraclass Neocopepoda<Subclass Copepoda<Class Maxillopoda < Subphylum Crustacea < Phylum Arthropoda There are five genera of calanoid copepods that make up the bulk of plankton samples. There are the locally produced genera of ***Acartia,* *Eurytemora*** and ***Tortanus*** and the two genera produced outside of Passamaquoddy Bay; ***Calanus*** and ***Pseudocalanus.*** Less important genera are ***Temora*** and ***Metridia.*** ***Acartia*** is the most common most of the time and is found near surface.
Family Euphausiidae	Superorder Peracarida < Order Euphausiacea < Subclass Eumalacostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda ***Thysanoessa inermis*** (Kroyer, 1846) Vertically migrates to surface at night to feed on phytoplankton, detritus and small zooplankton when phytoplankton not available. Able to store lipids and starve for up to two months.
Subfamily Mysinae	Family Mysidae < Order Mysida < Superorder Peracarida < Subclass Eumalacostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda ***Neomysis Americana*** (S.I. Smith, 1873) Feed on phytoplankton and zooplankton. As selective feeders they have the potential of structuring zooplankton communities.

Infraorder Cladocera	Suborder Onychocaudata < Order Diplostraca < Subclass Phyllopoda < Class Branchiopoda < Subphylum Crustacea < Phylum Arthropoda ***Podon sp.*** ***Evadne sp.*** Consume particles between twenty and one hundred twenty microns such as diatom and dinoflagellate phytoplankton, tintinnids, small copepod eggs and copepod nauplii. (Jagger et al., 1988).
Order Cumacea	Superorder Peracarida < Subclass Eumalacostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda ***Diasylis sp.*** deposit feeder
Limacina helicina (Phipps, 1774)	Superfamily Limacinoidea < Suborder Euthecosomata < Order Thecosomata < Infraclass < Subclass Heterobranchia < Class Gastropoda < Pylum Mollusca ***Limacina helicina*** is a flux feeder that uses a mucous net. The net extends over the top of the plankter and can be deployed rapidly, allowing it to take advantage of settling particles.
Oikopleura (vexillaria) labradoriensis Lohmann, 1933	Tribe Labiata <Subfamily Oikopleurinae < Family Oikopleuridae < Order Copelata <Class Appenidularia < Subphylum Tunicata < Phylum Chordata ***Oikopleura (vexillaria) labradoriensis*** builds a “house” of protein and cellulose with complex structure that, combined with regular beating of the tail, concentrates food particles prior to feeding. A pair of mucous nets that are produced by the pharynx filter the concentrate before being drawn into the digestive tract. This is very efficient and facilitates feeding on particle sizes down to nanoplankton. The house is discarded when the filters are clogged several times a day and discarded houses account for a significant fraction of sinking organic matter.
Subclass Copepoda nauplius larva	Class Maxillopoda < Subphylum Crustacea < Phylum Arthropoda Copepod nauplii either entrain prey with a feeding current or are ambush predators. Ambush predators are able to detect prey remotely and jump past the target, causing the prey to flow towards their mouth. Nauplii that use feeding currents detect prey when it contacts setae.

Lepeophtheirus salmonis (Kroyer, 1837) larva to sub-adult	Family Caligidae < Order Siphonstomatoida < Superorder Podoplea < Infraclass Neocopepoda < Subclass Copepoda < Class Maxillopoda < Subphylum Crustacea < Phylum Arthropoda ***Lepeophtheirus salmonis*** is an ectoparasite of salmon with short duration, non-feeding larval stages.
Order Decapoda larva	Subclass Eumalacostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda Nearly all of the larvae are crab. The feeding strategy of crab larvae is a combination of omnivory and selection.
Family Euphausiidae larva	Superorder Peracarida < Order Euphausiacea < Subclass Eumalacostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda Aggregates produced by Class Appendicularia, the “house” builder, are used as food by euphausiid larvae, copepods and planktiverous fish in the Gulf of California (Alldredge, 1976).
Infraclass Cirripedia larva	Subclass Thecostraca < Class Maxillopoda < Subphylum Crustacea < Phylum Arthropoda There are four to six naupliar stages that are either lecithotrorphic or planktotrophic (Strathman, 1987). The final nauplius molts into a non-feeding cyprid larval form which is unique to cirripedes and is responsible for finding a suitable habitat where it can settle and undergo final metamorphosis into a sessile life of filtering plankton.
Class Bivalvia larva	Phylum Mollusca Bivalve larvae are vertically mobile and may be found at the layer of maximum food concentration in a stratified water column (Raby et al., 1994). They are suspension feeders and will injest carmine particles suspended in seawater.
Class Polychaeta larva	Phylum Annelida Polychaete larvae feeding mechanisms vary greatly; most are filtrating downstream collectors involving two ciliated bands that retain particles of between two and twenty microns (Martin et al., 1996).

Phylum Echinodermata larva	Phylum Echinodermata Echinoderm larvae are slow swimmers that use a combination of morphology and ciliated bands to deflect particles into the mouth. Comparative studies of form and function in suspension feeding are ideally suited for larvae of this Phylum (Hart, 1991).
Order Aplousobranchia larva	Class Ascidiacea < Phylum Chordata Larvae are not capable of feeding and are said to “eat their own brain” because the cerebral ganglion, responsible for movement, is reduced during metamorphosis
Infraclass Facetoetecta larva	Subclass Thecostraca < Class Maxillopda < Subphylum Crustacea < Phylum Arthropoda Larvae are lecithotrophic (nonfeeding).
Order Amphipoda	Superorder Pericarida < Subclass Eumalocostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda Family Hyperiidae ***Themisto compressa*** ***T. abyssorum*** Visual predator on mesozooplankton – large double structured eyes. Raptorial predators on calanoid copepods (Kraft et al, 2013).
Parasagitta elegans (Verrill, 1873)	Phylum Chaetognatha ***Parasagitta elegans*** Cruising raptorial predator of copepods and fish larvae.
Class Polychaeta ***Tomopteris helgolandica*** Greeff, 1879 ***Autolytus sp.***	Phylum Annelida Family Tomopteridae ***Tomopteris helgolandica*** feeds on herring larvae and Chaetognatha using eversible sac-like pharynx. Family Syllidae ***Autolytus sp.*** associated with hard substrates and feeds on hydroids, bryozoans and other colonial invertebrates using jaws.
Order Isopoda	Superorder Pericarida < Subclass Eumalocostraca < Class Malacostraca < Subphylum Crustacea < Phylum Arthropoda

Class Ostracoda	Subphylum Crustacea < Phylum Arthropoda
Superclass Gnathostomata (fish) larva	Subphylum Vertebrata < Phylum Chordata
Pleurobrachia pileus (O. F. Muller, 1776)	Family Pleurobrachiidae < Order Cyddipida < Subclass Typhlocoela < Class Tentaculata < Phylum Ctenophora ***Pleurobrachia pileus*** Vertically migrating ambush entangling predator that feeds on zooplankton, especially copepods and small fish larvae.
Phylum Cnidaria Family Ulmaridae ***Aurelia aurita*** (Linnaeus, 1758)	***Aurelia aurita*** is the most common but there are many other species They feed on slow escape prey like cirripede (barnacle) and small fish larvae with greater efficiency than they do for fast escape prey like copepods.

Biological conditions diversity, density and phenology

Fine mesh vertical plankton tow monthly time series: August 2011 – February 2015

In these graphs the time series of density (number per cubic meter) of more than two dozen zooplankton taxa have been put into functional groups, eggs and larvae. Dots on the abscissa mark sampling dates. November and December of 2012 were sampled twice.

This net samples small copepods and larvae that would be missed by the coarse mesh net.

Setal feeders	Calanoid Calanoida Euphausiidae Mysinae Cladocera Cumacea
Mucous feeders	shelled Pteropoda Larvacea
Eggs	invertebrate fish
Larvae	Copepoda parasitic Copepoda Decapoda Euphausiidae Cirripedia parasitic Cirripedia Bivalvia Polychaeta Aplousobranchia Echinodermata
Type 1 predator– raptorial	Amphipoda Chaetognatha Polychaeta Isopoda Ostracoda fish larva
Type 2 predator- entangling gelatinous	tentacled Ctenophora Cnidaria

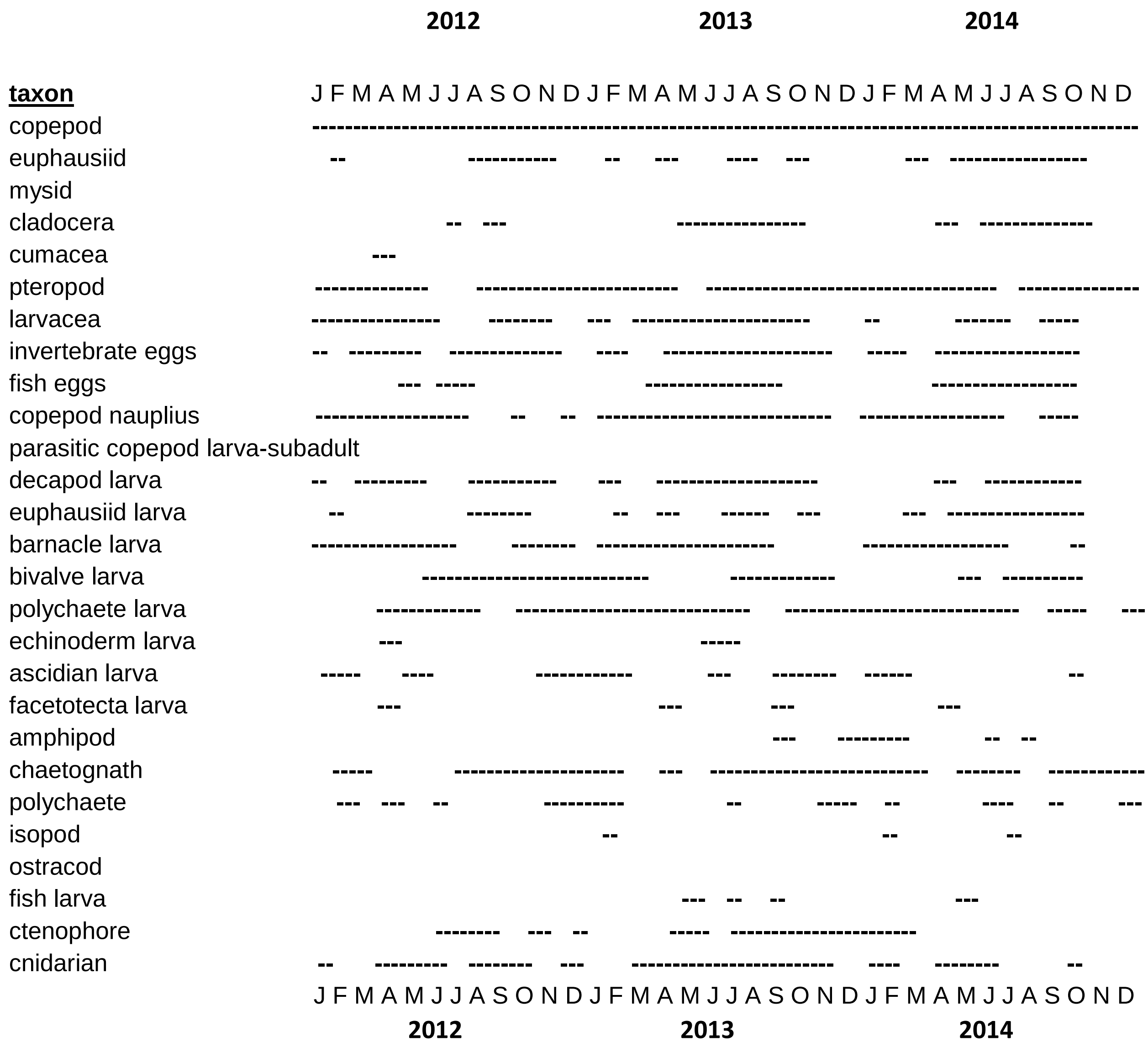


Figure 18. Presence absence over three years of several zooplankton taxa and eggs from fine mesh vertical plankton tow series at station Prince 6.

Setal feeders

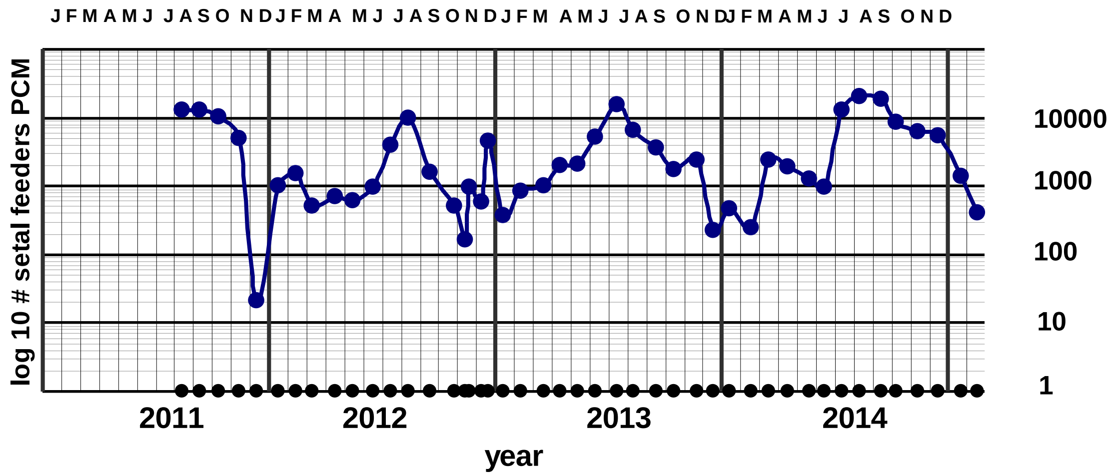


Figure 19. Setal feeding plankton density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot. Copepoda are the main component of this group which includes Euphausiacea, Mysinae, Cladocera and Cumacea.

From 2011 to 2014 all density peaks were in August except for 2013 when the peak was in July. Maximum density has also gradually increased up to 2014 with a peak density of eleven thousand per cubic meter.

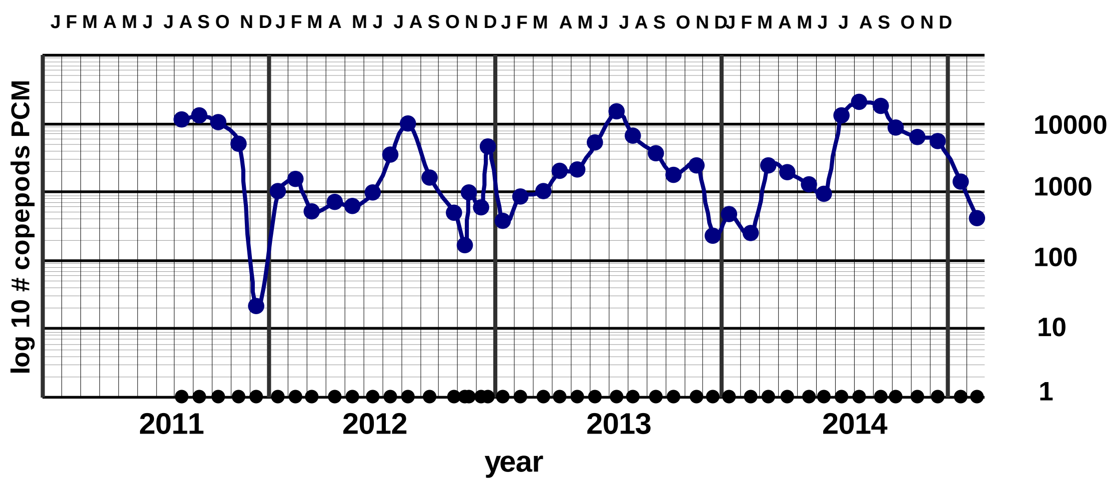


Figure 20. Calanoid Copepoda density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Almost all of the setal feeders are calanoid copepods. From 2011 to 2014 all density peaks were in August except for 2013 when the peak was in July. Maximum density has also gradually increased up to 2014 with a peak density of eleven thousand per cubic meter.

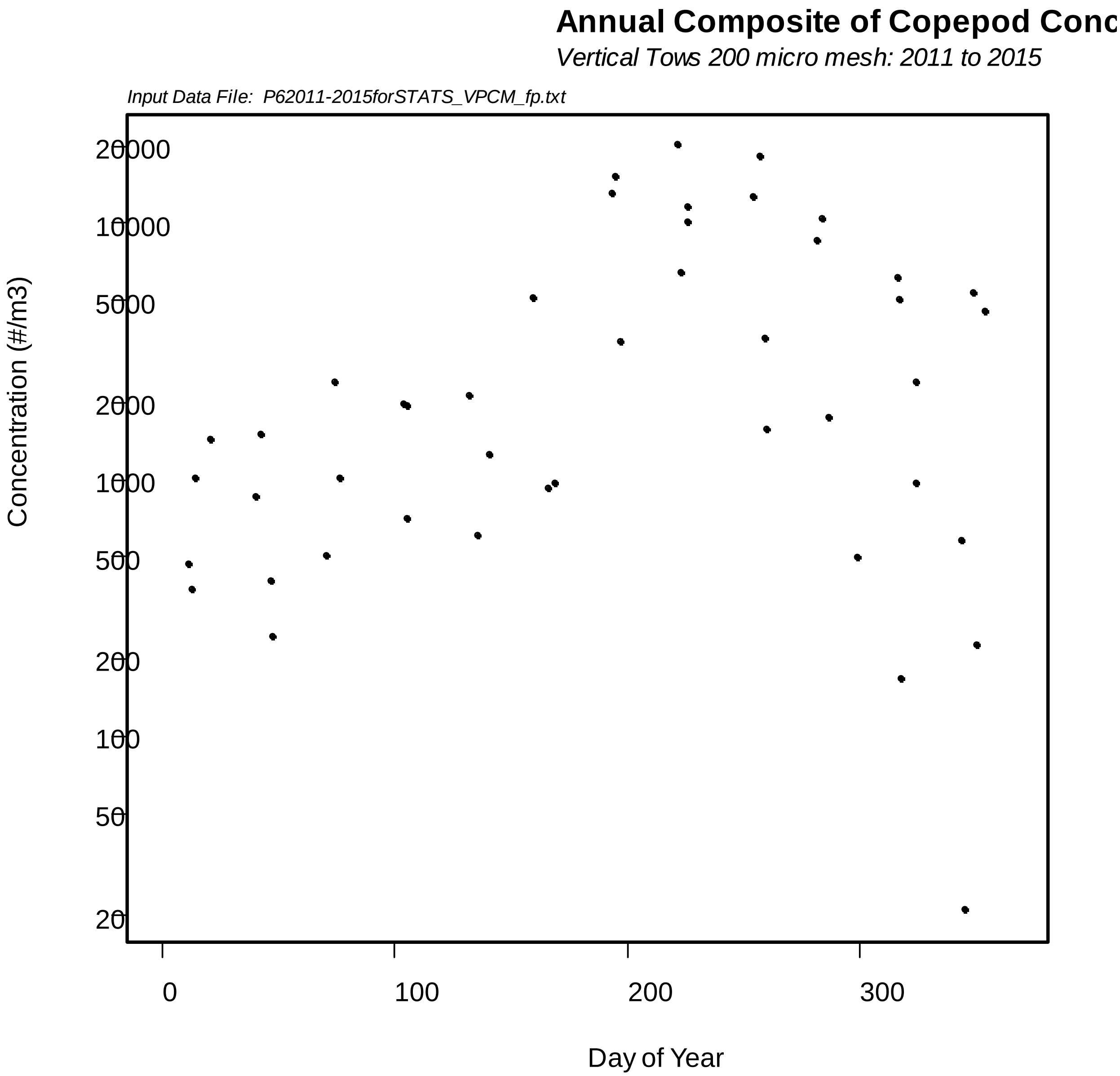


Figure 21. Annual composite of calanoid copepod concentration.

Calanoid copepod maximum concentration is found between Julian day 200 and 250.

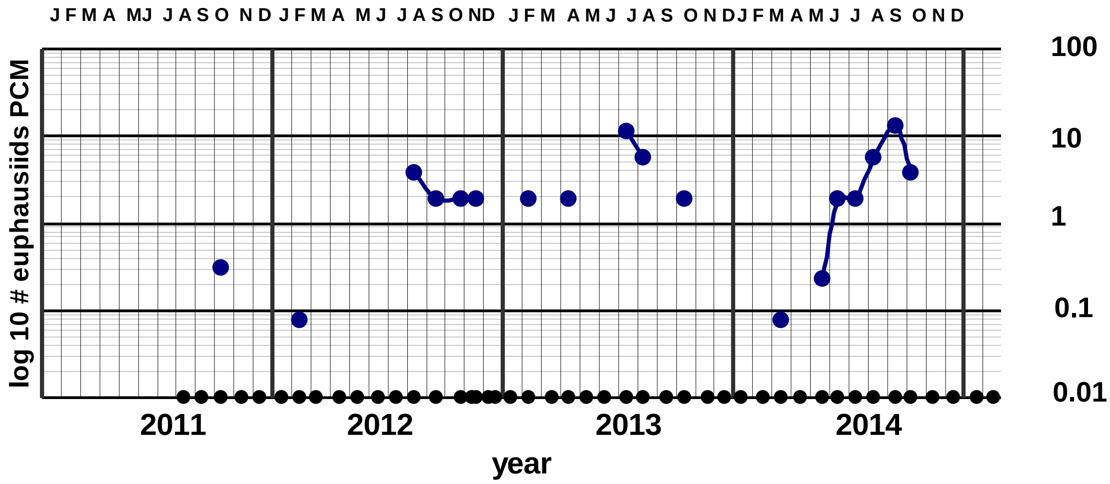


Figure 22. Euphausiidae density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Fall density of Euphausiids increased almost an order of magnitude between 2011 and 2012. In 2013 it was the same as the previous year and in 2014 it increased to four per cubic meter. There were noticeably more observations of this taxon in 2014 than in the past.

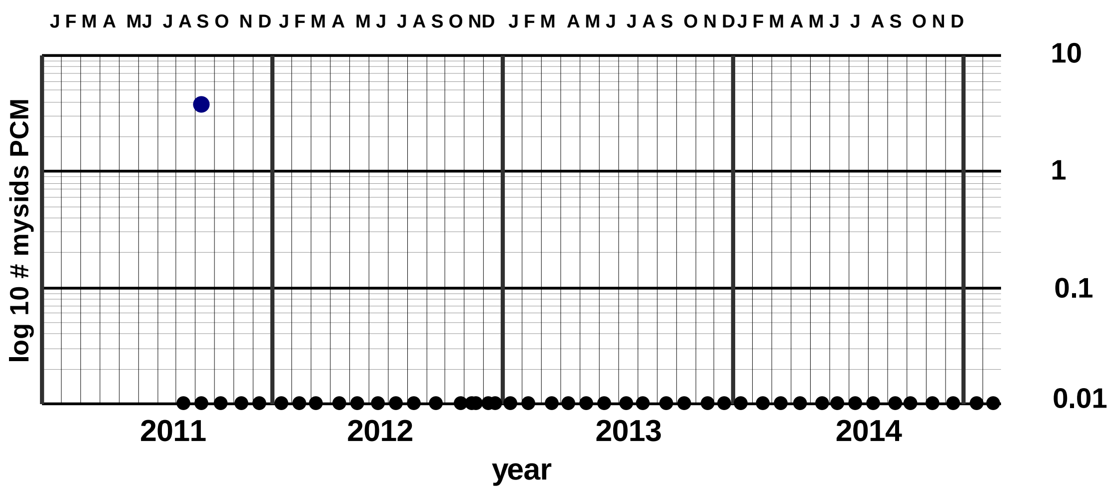


Figure 23. Mysinae density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

There was only one observed catch of mysids in September of 2011 from the vertically towed net.

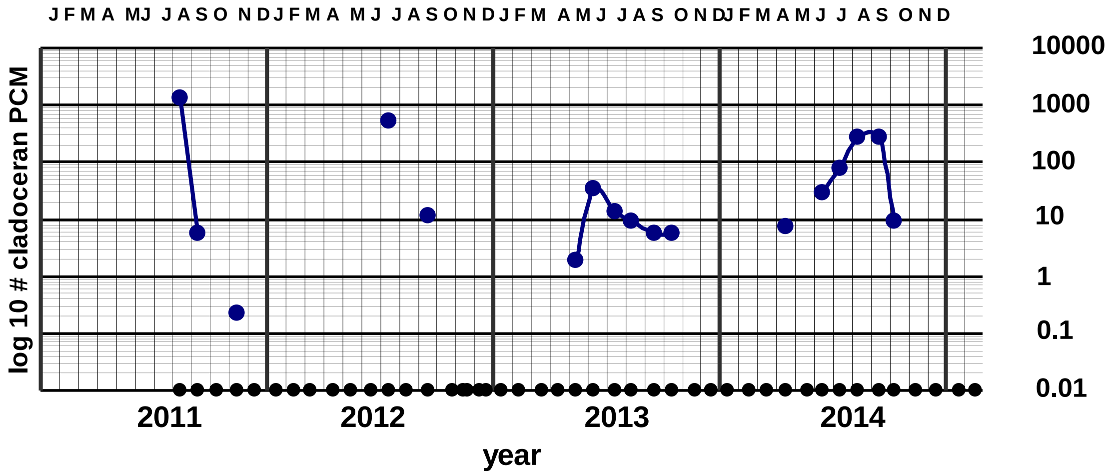


Figure 24. Cladocera density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Peak density was observed in July of 2012 and 2013 and in August of 2011 and 2014. Cladocerans are more common in samples from the past two years than they were in previous samples.

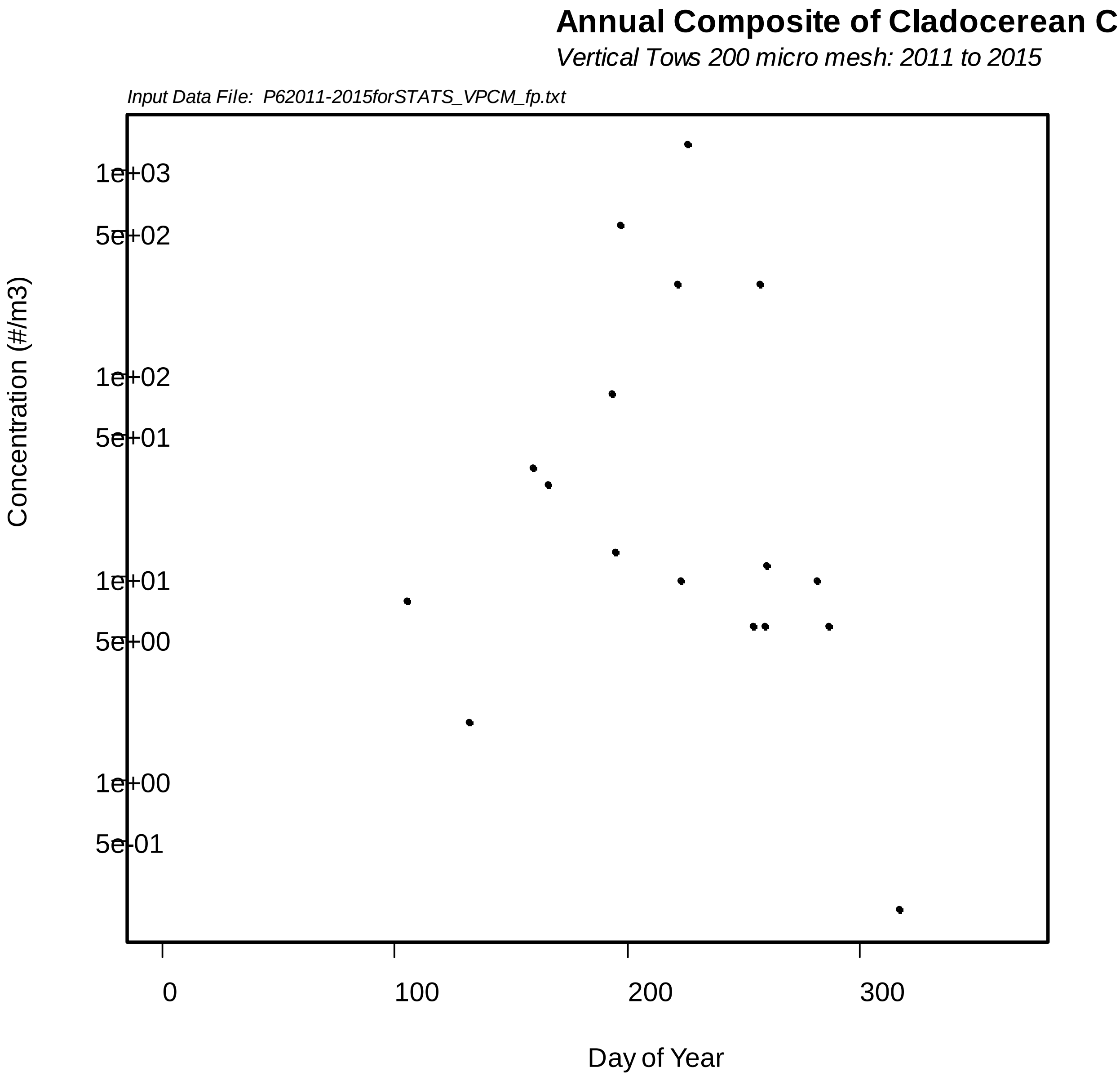


Figure 25. Annual composite of cladoceran concentration.

Cladoceran maximum concentration is found between Julian day 200 and 230.

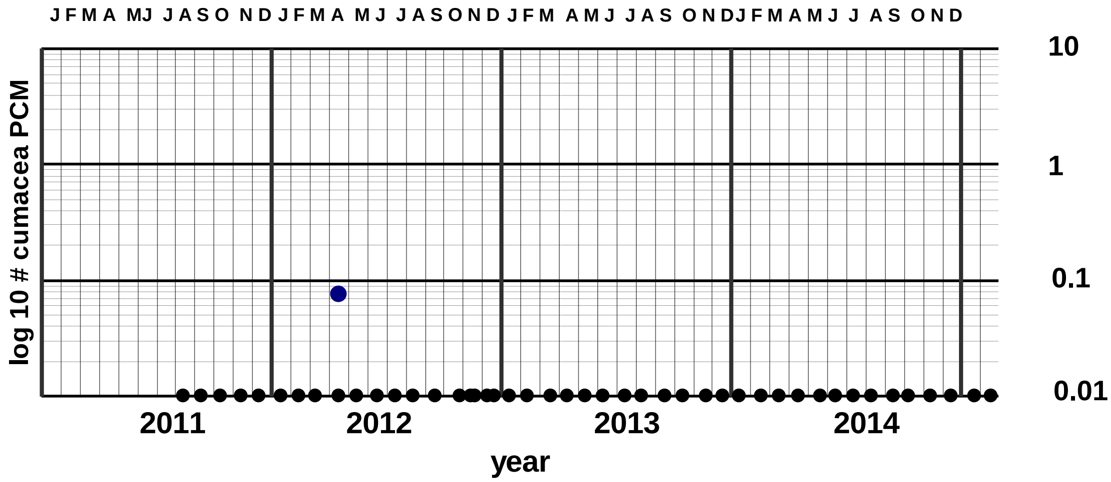


Figure 26. Cumacea density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

There was only one observed catch of cumaceans in April of 2012 from the vertically towed net.

Mucous feeders

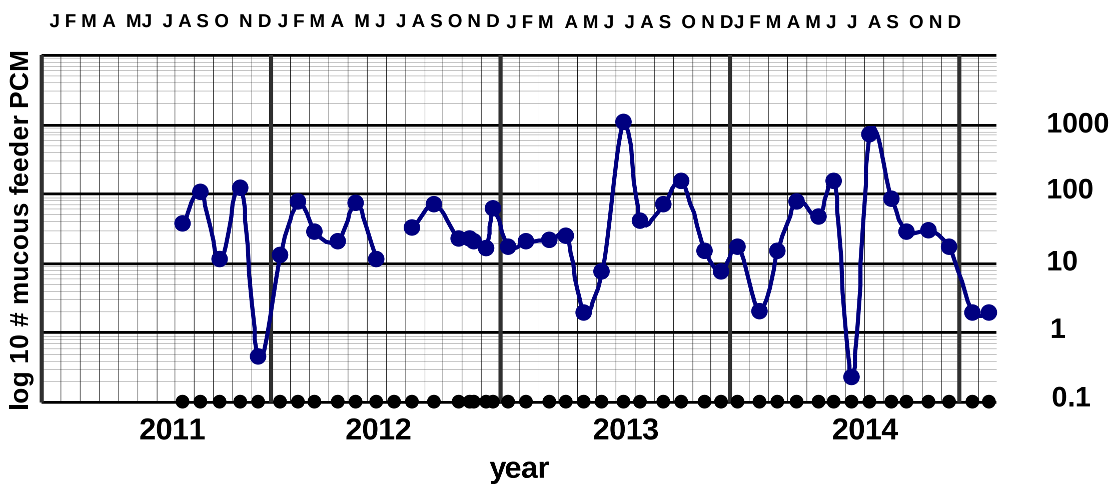


Figure 27. Mucous feeder density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot. Pteropoda and larvace are part of this group.

Mucous feeders were found in all but one of our samples; July of 2012. Density was usually between ten and one hundred per cubic meter. There are distinct peaks of density of about one thousand per cubic meter in July and August of 2013 and 2014 respectively.

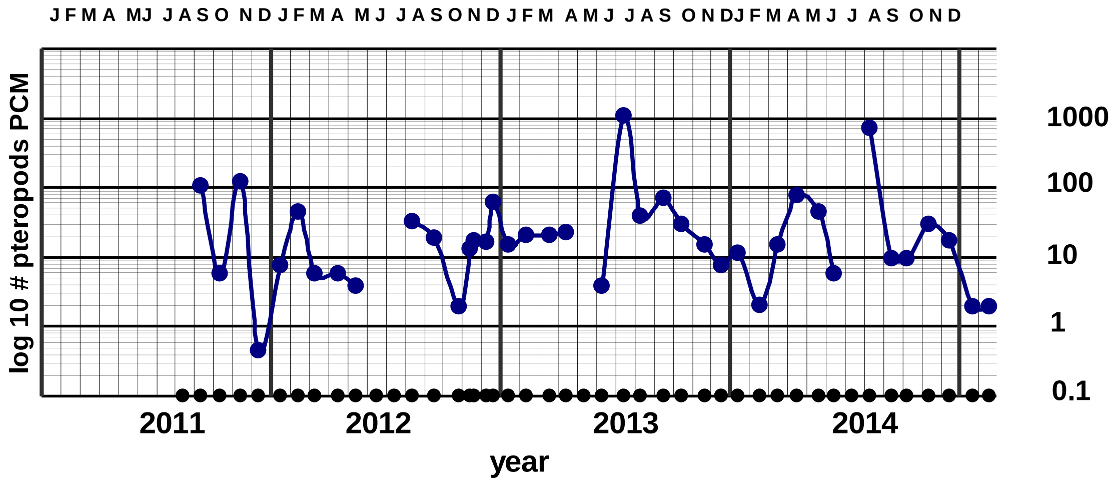


Figure 28. Pteropoda density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Pteropods were present every year from late summer through to the summer of the following year. There were peaks of about a thousand per cubic meter in July and August of 2013 and 2014 respectively.
For three of the last four fall and winter seasons (2011-2012 to 2014-2015) there was a one to three order of magnitude decline in pteropod density. In the fall and winter of 2012-2013 density remained above ten individuals per cubic meter.

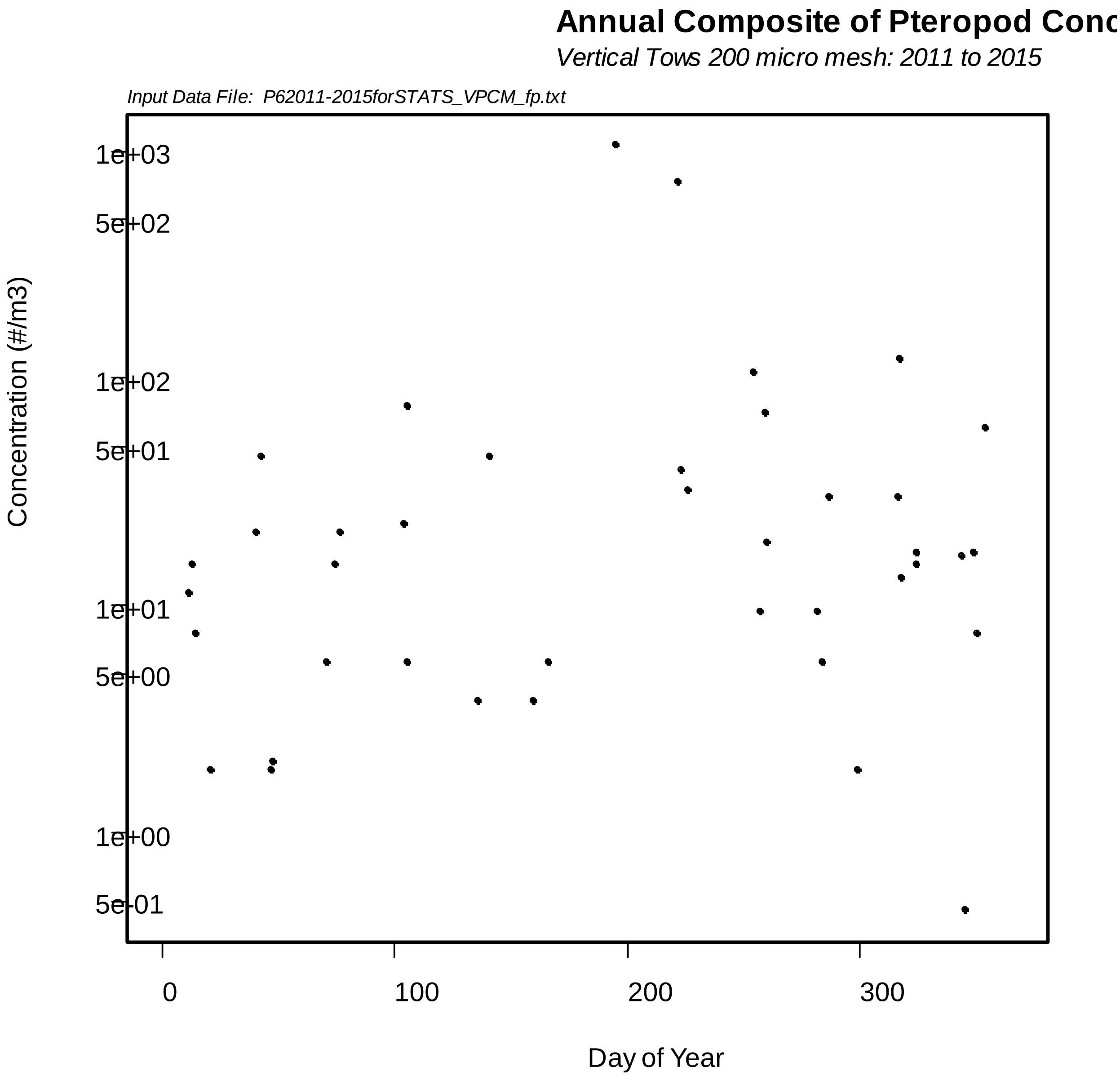


Figure 29. Annual composite of ***Limacina helicina*** concentration.

Limacina helicina maximum concentration is found between Julian day 190 and 220.

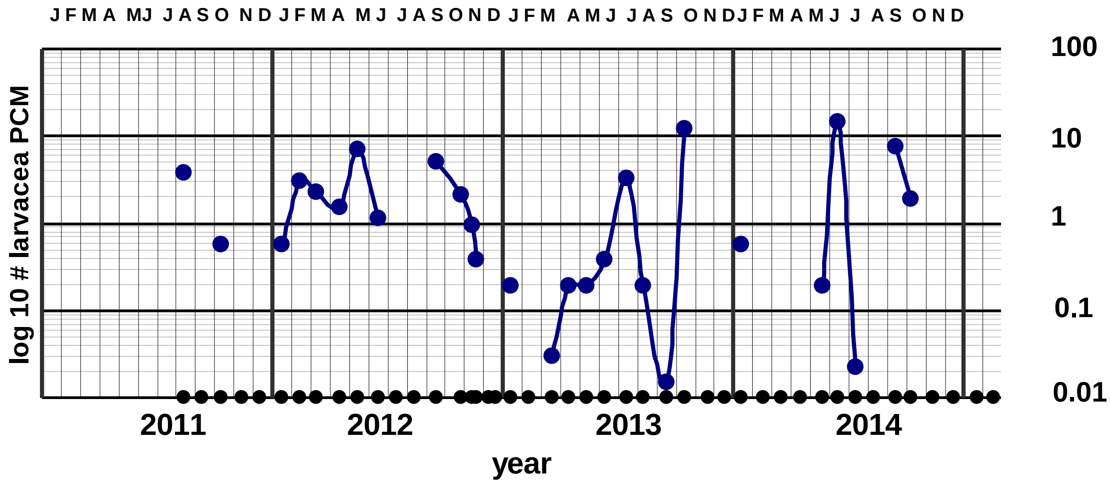


Figure 30. Larvacea density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Larvacea were noted in nine months of 2012 and 2013. They were only present for six months in 2014.

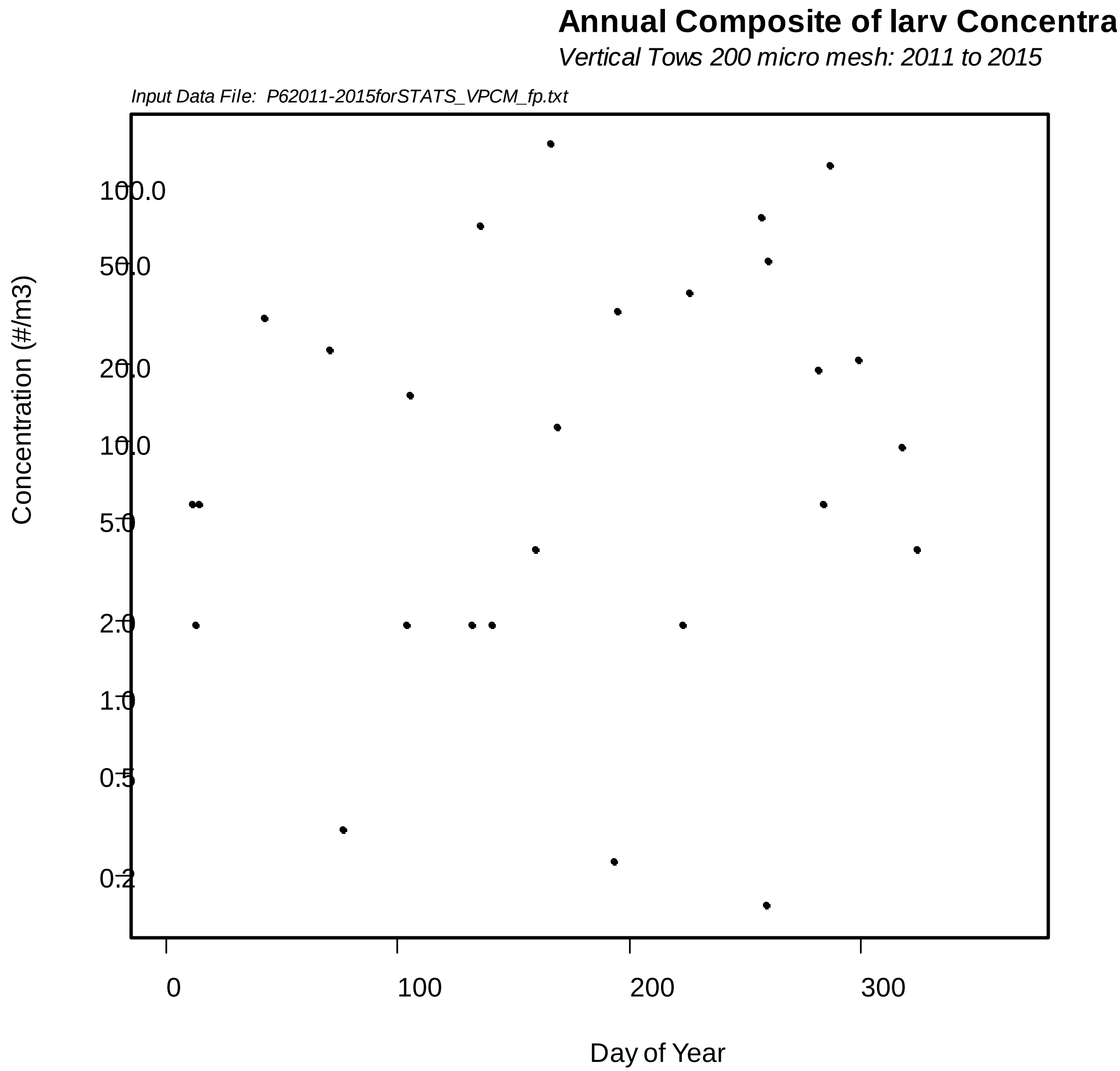


Figure 31. Annual composite of ***Oikopleura (vexillaria) labradoriensis*** concentration.

Oikopleura (vexillaria) labradoriensis maximum concentration is found between Julian day 130 and 290.

Eggs

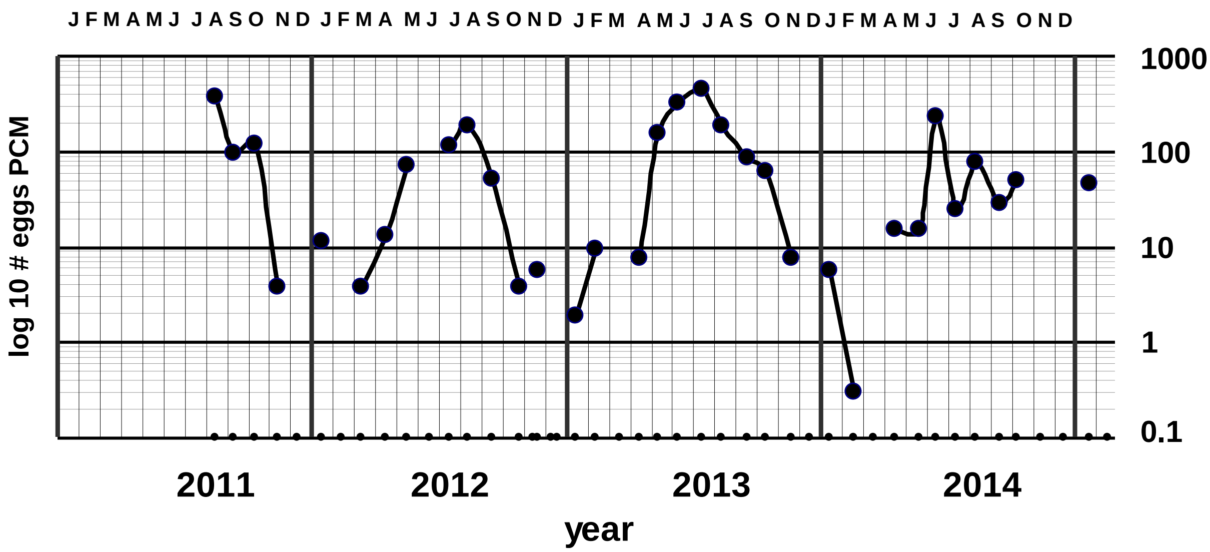


Figure 32. Total egg density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Eggs were almost all from invertebrates. There was peak density of more than one hundred per cubic meter in August of 2011 and 2012, in July of 2013 and in June of 2014. Fewer eggs were seen in 2014 than in the previous three years,

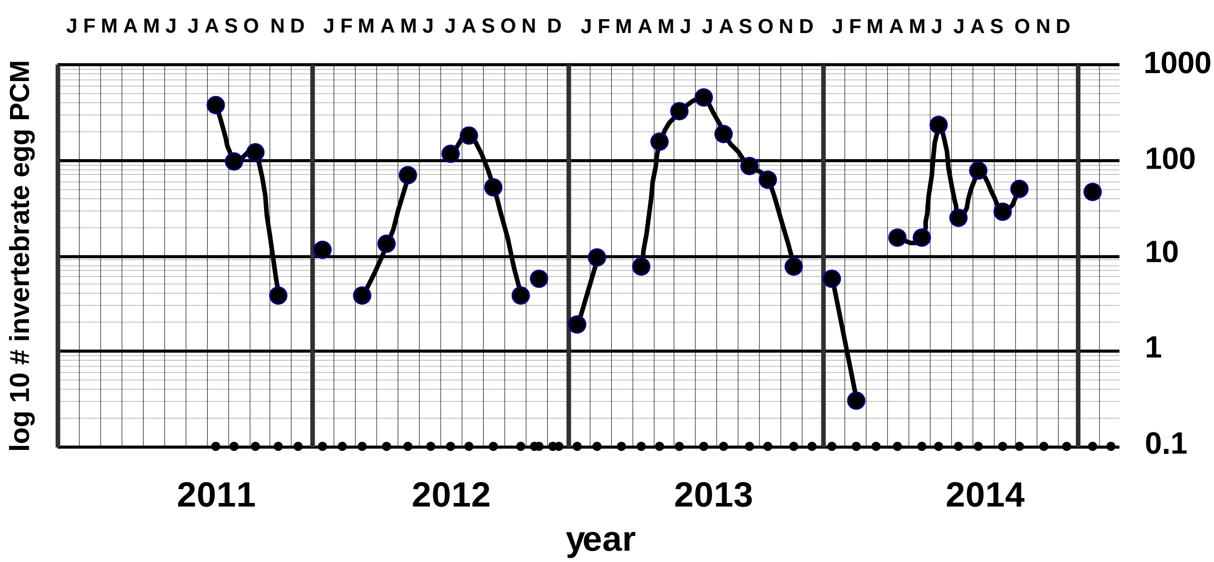


Figure 33. Invertebrate egg density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

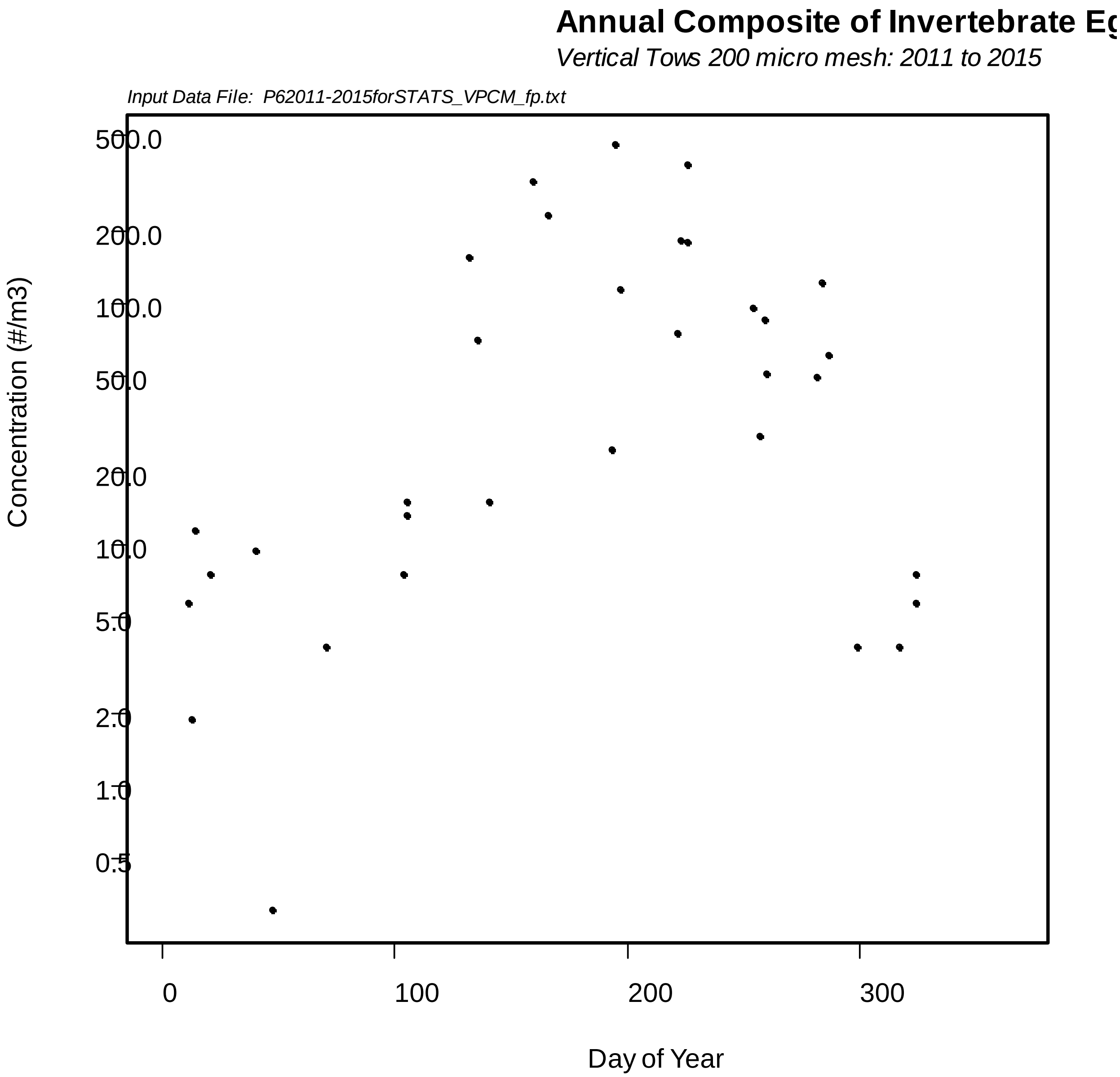


Figure 34. Annual composite of invertebrate egg concentration.

Invertebrate egg maximum concentration is found between Julian day 130 and 290.

There was peak density of more than one hundred per cubic meter in August of 2011 and 2012, in July of 2013 and in June of 2014. Fewer eggs were seen in 2014 than in the previous three years,

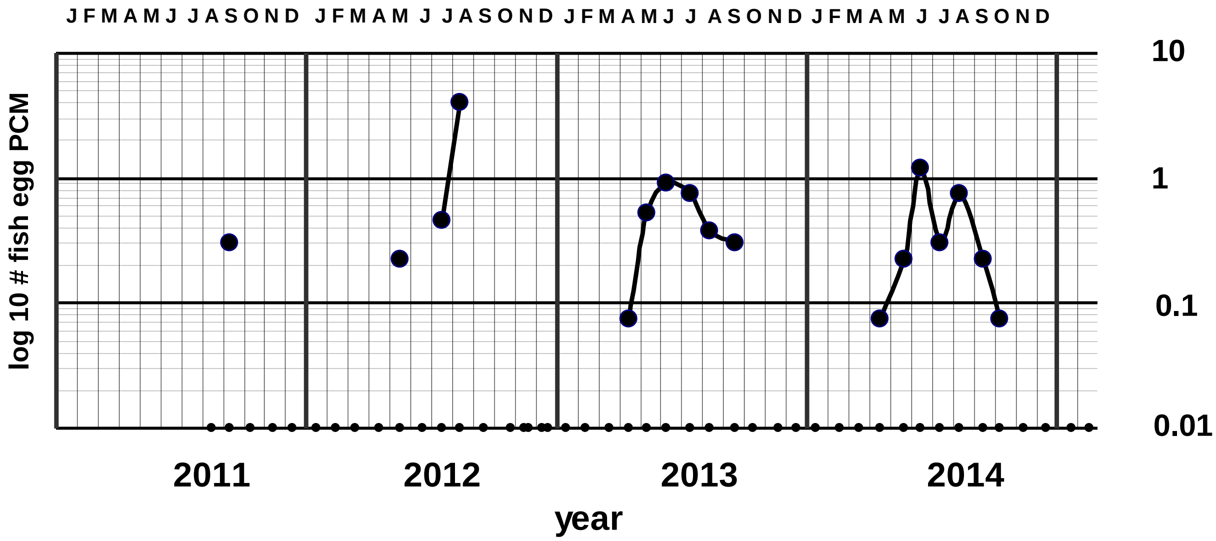


Figure 35. Vertebrate (fish) egg density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Fish egg density was greatest during June of 2013 and 2014. There were only three catches of fish larvae in 2012. In 2013 there were six catches and in 2014 there were seven.

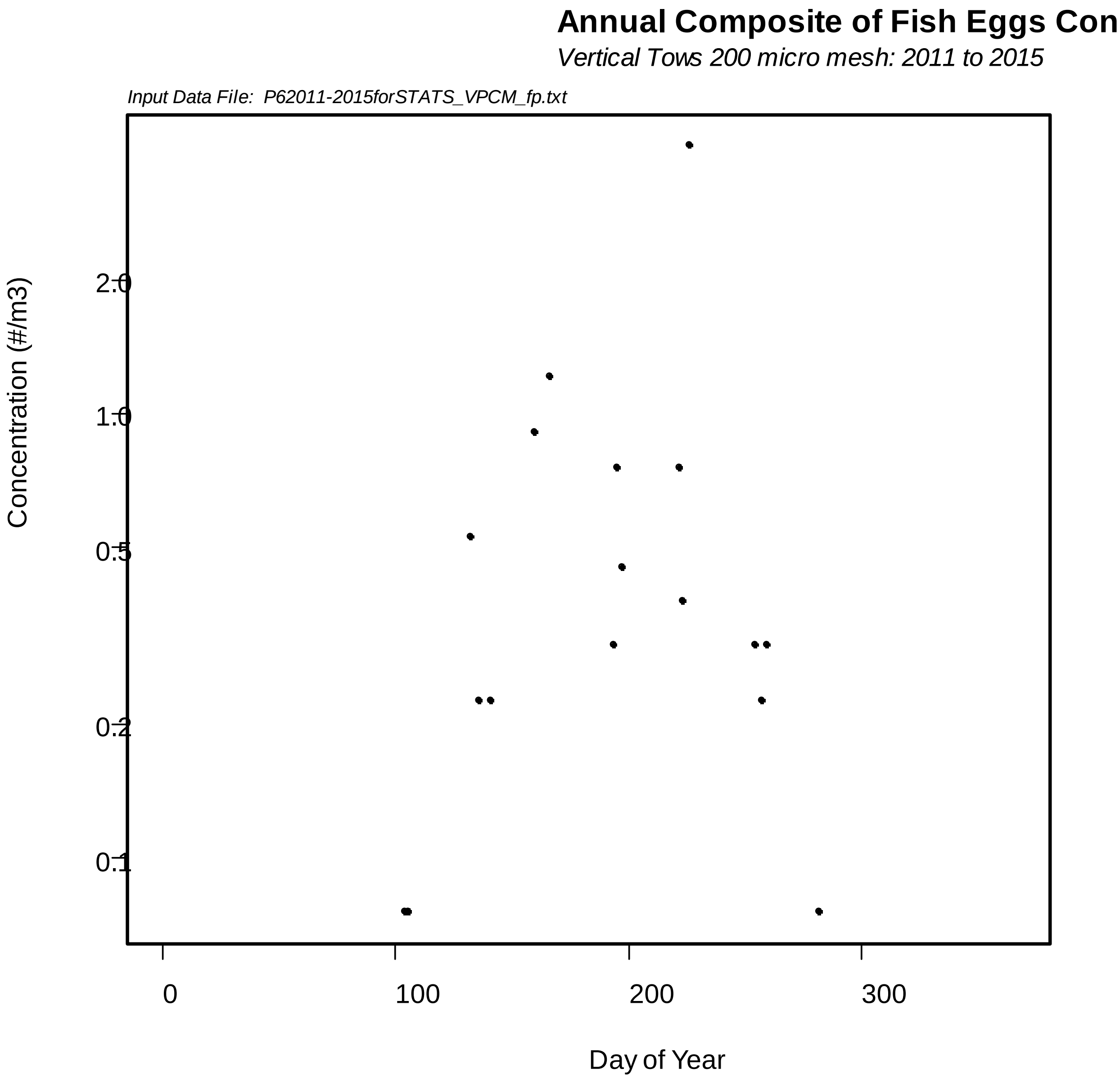


Figure 36. Annual composite of fish egg concentration.

Larvae

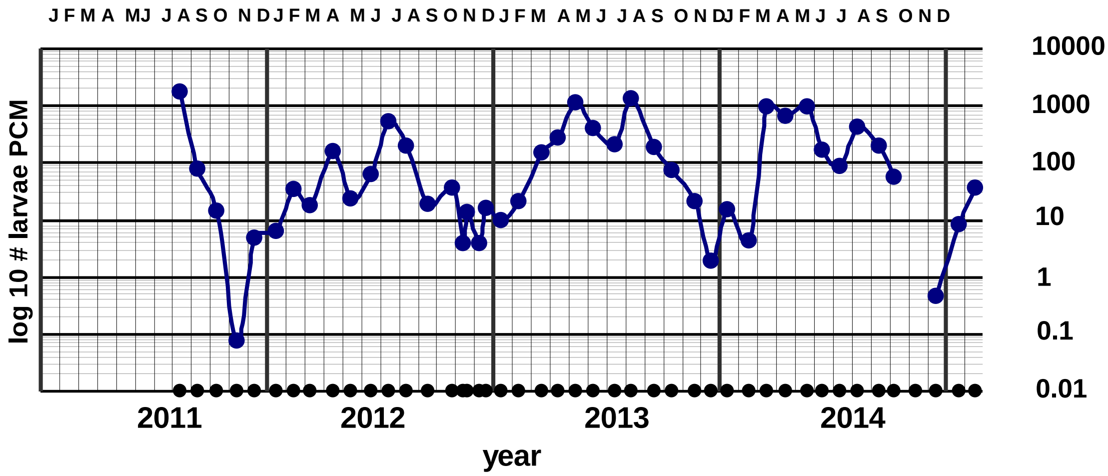


Figure 37. Larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot. Bivalve, barnacle and polychaete larva are the main component of this group which also includes copepod, parasitic copepod, parasitic barnacle, decapod, euphausiid, ascidian and echinoderm larvae.

Larvae reached a density of about a thousand per cubic meter between March and August between 2011 and 2014. They were gradually increasing.

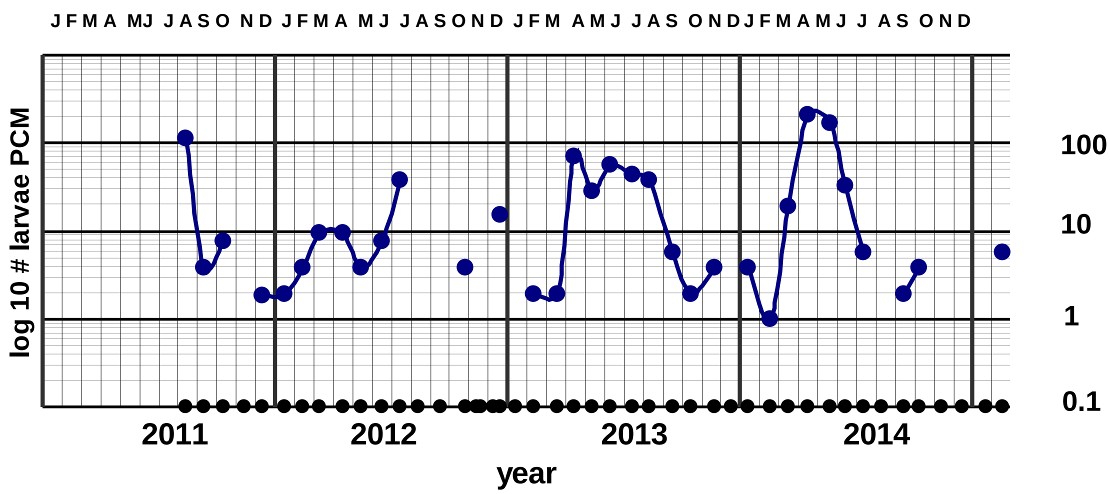


Figure 38. Copepoda nauplius larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Peaks of nauplius density occurred between April and August and seemed to be gradually increasing in magnitude.

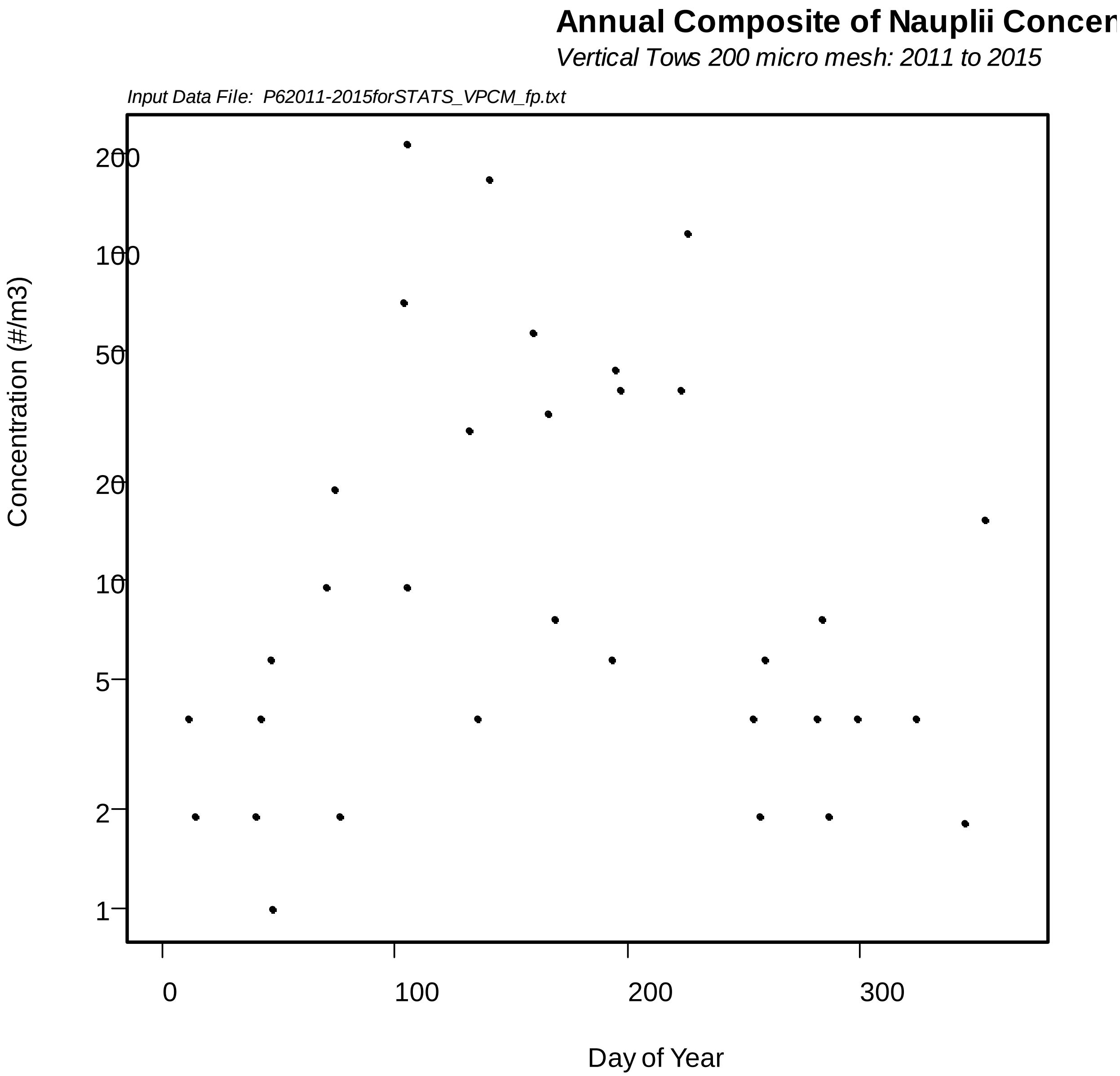


Figure 39. Annual composite of copepod nauplius larval concentration.

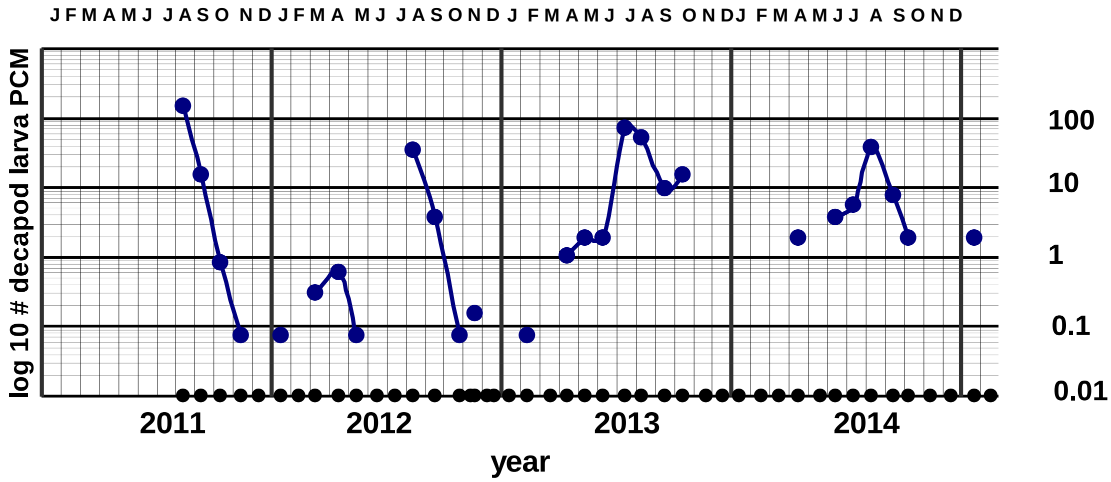


Figure 40. Decapoda larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Peaks of decapod larval density occurred between July and August and also showed a gradually increasing trend.

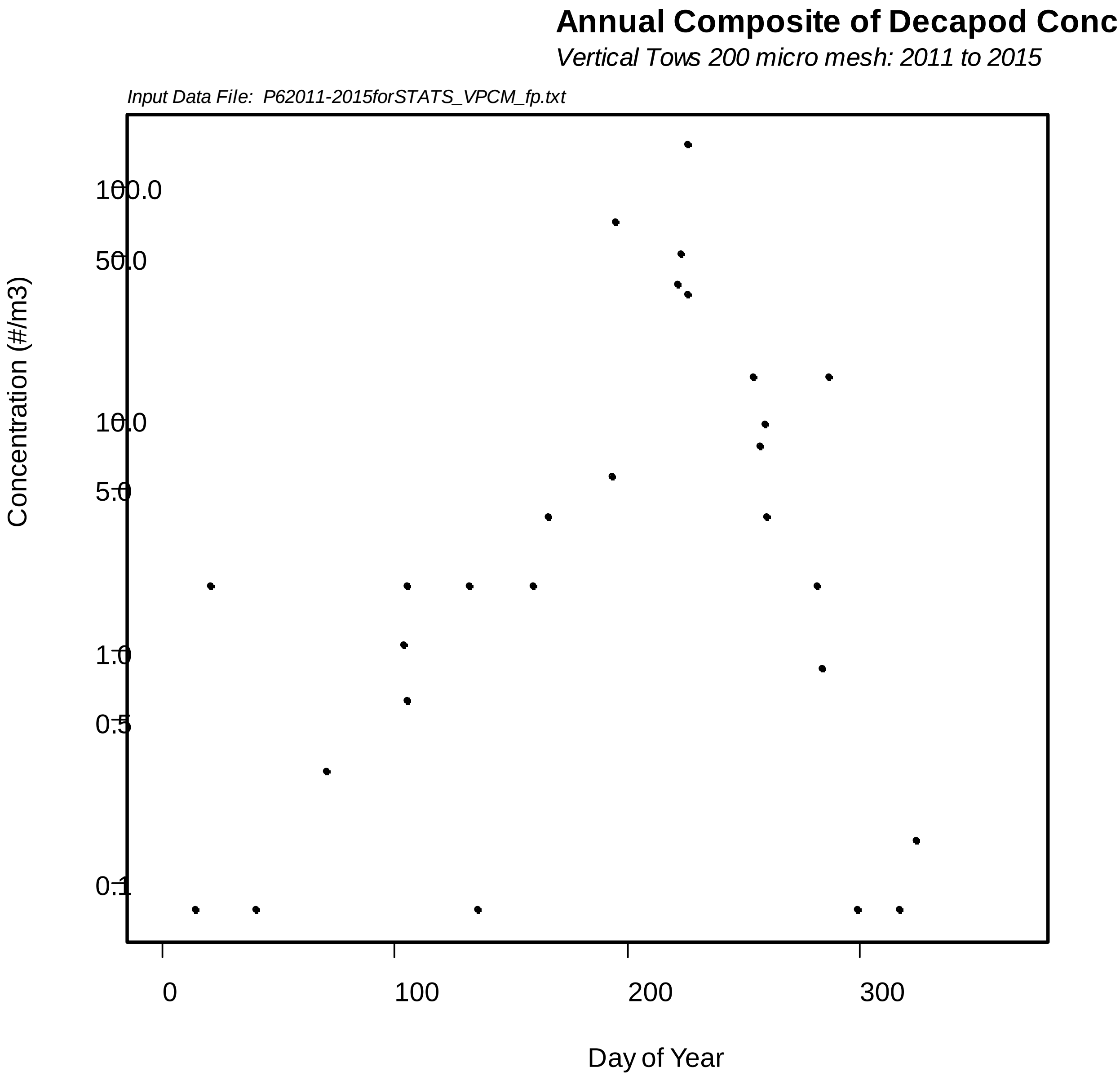


Figure 41. Annual composite of decapod larval concentration.

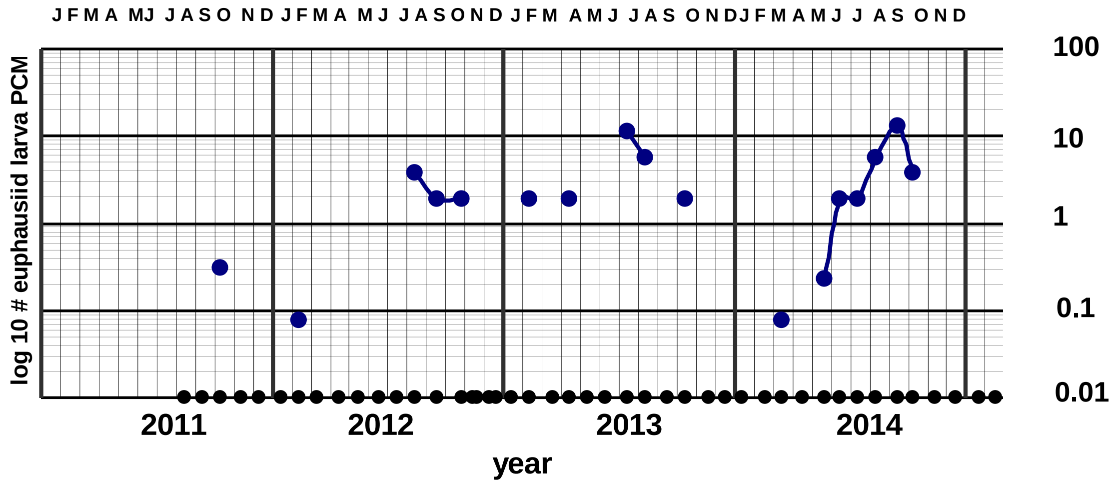


Figure 42. Euphausiidae larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Euphausiid larval density peaks occurred between July and September, and, like other groups, seemed to show an increasing trend from less than one to more than ten per cubic meter.

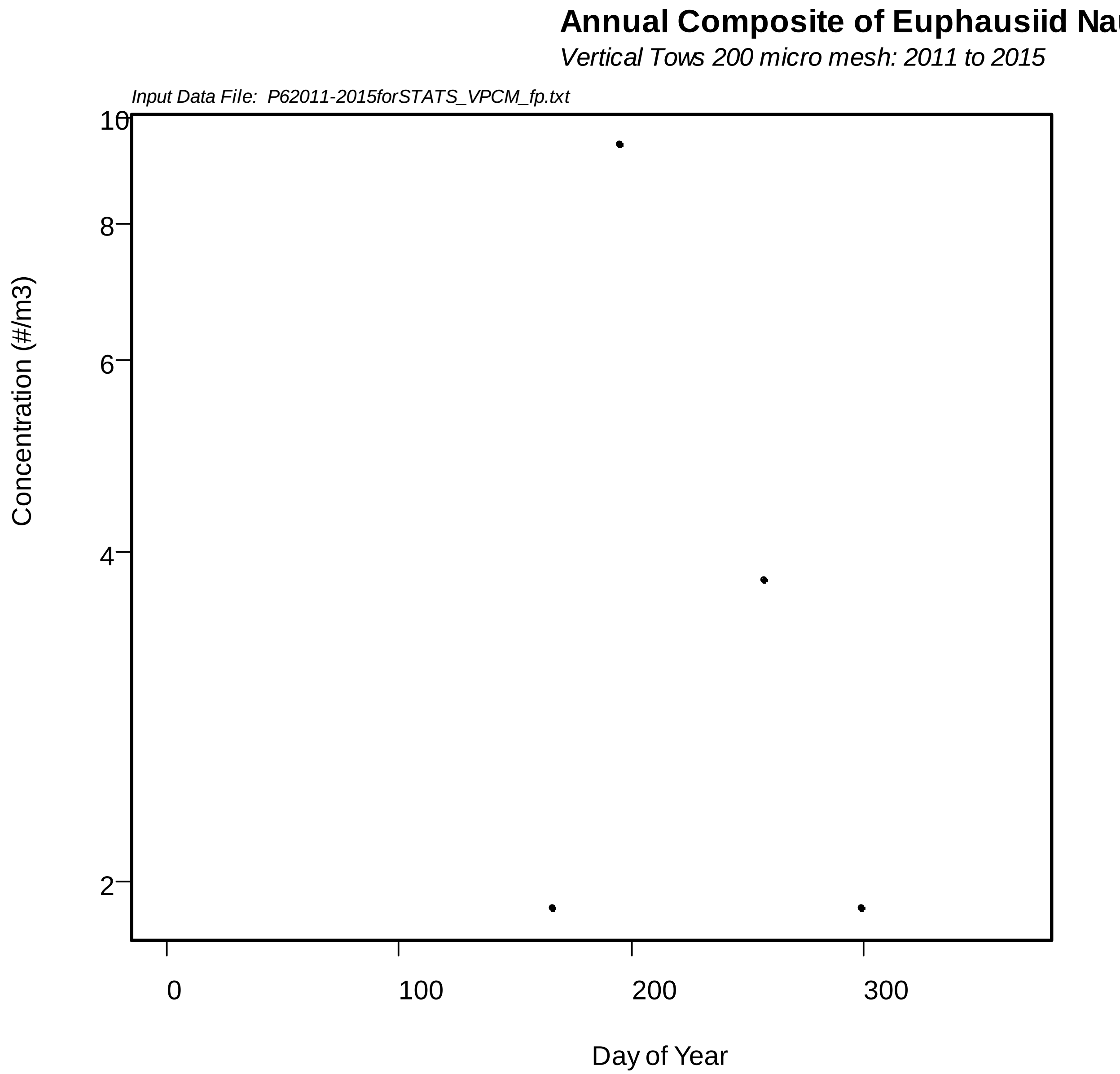


Figure 43. Annual composite of euphausiid nauplius larval concentration.

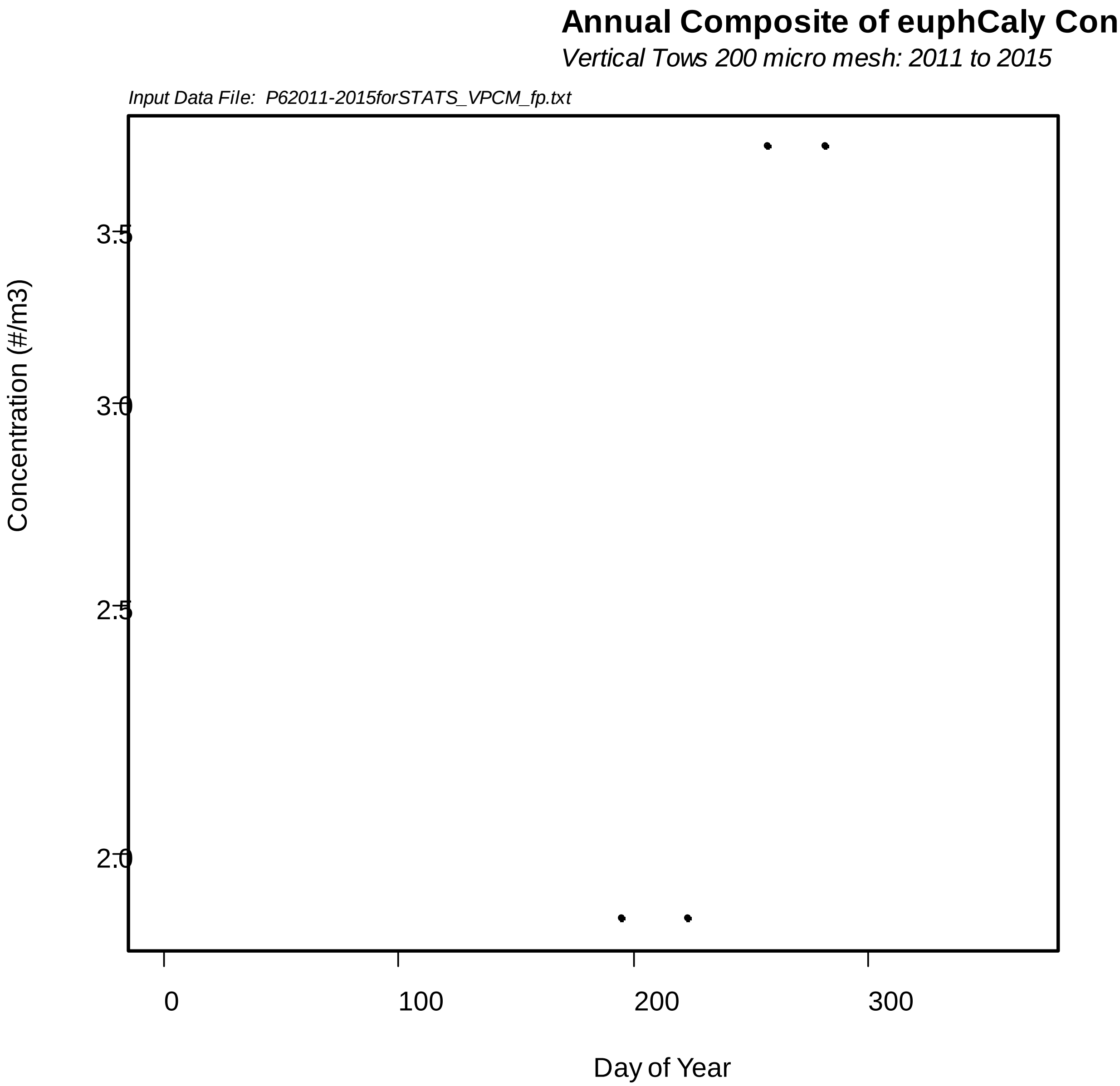


Figure 44. Annual composite of euphausiid calyptopis larval concentration.

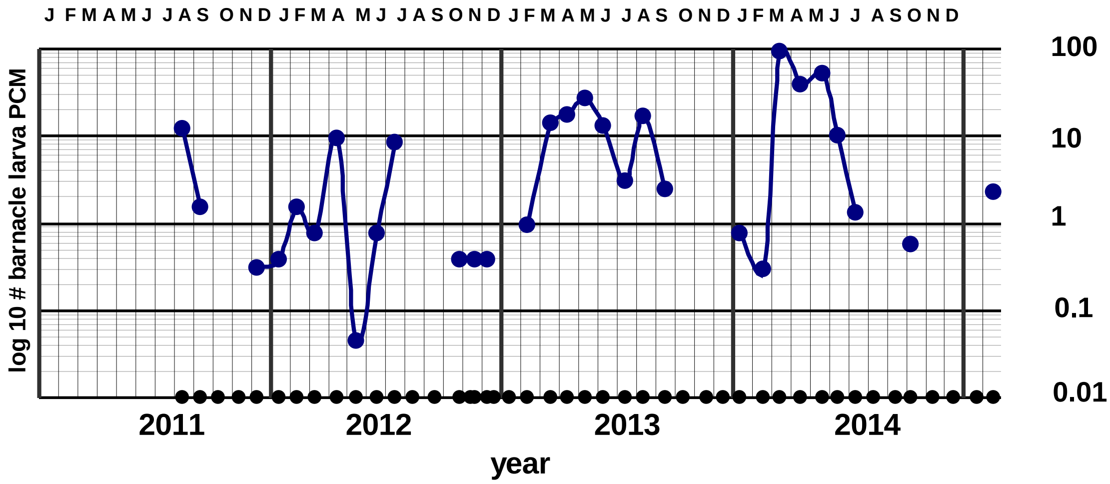


Figure 45. Cirripedia larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Barnacle larvae exhibited peak density between March and August and showed an increasing trend from ten to one hundred per cubic meter.

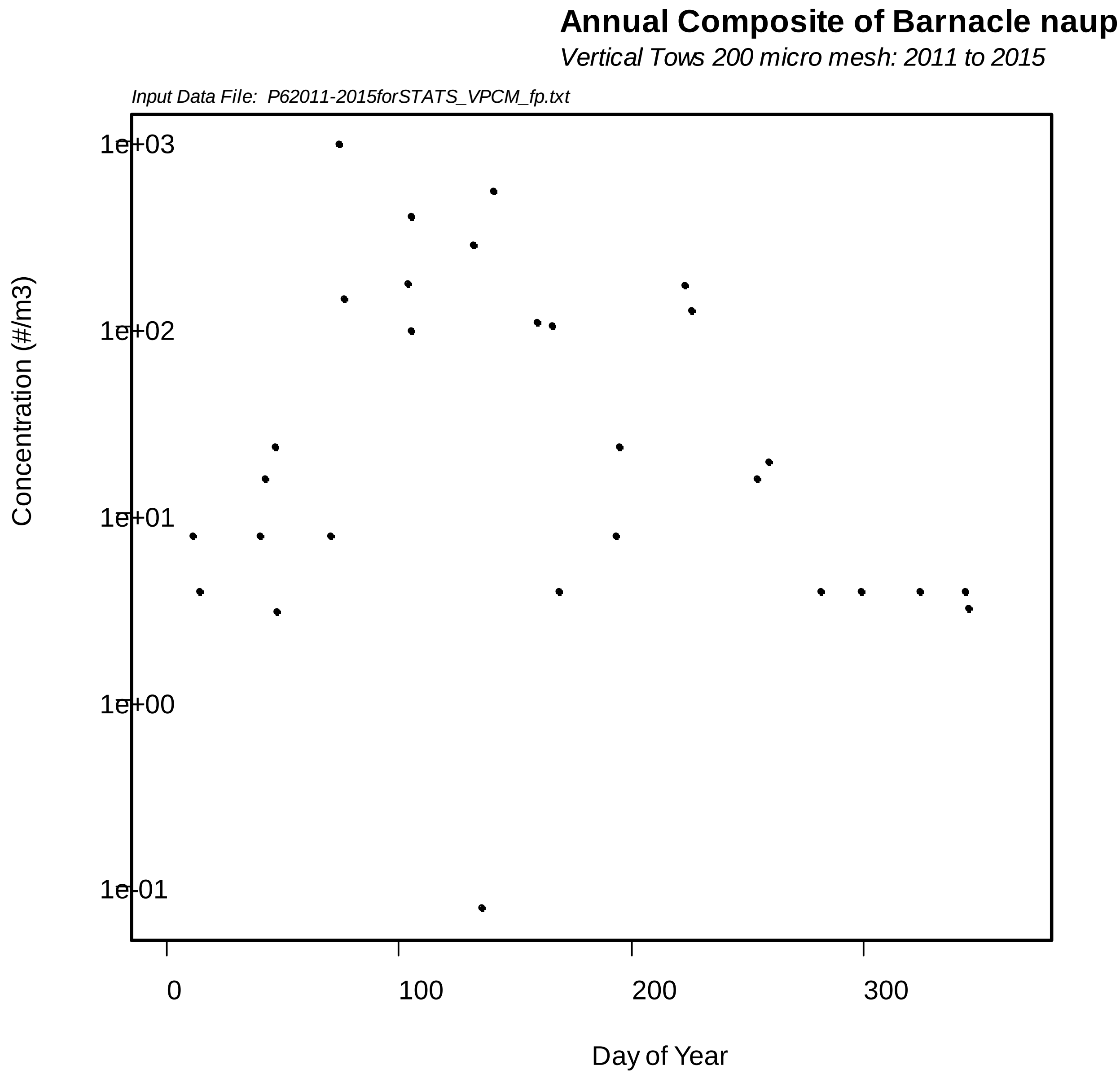


Figure 46. Annual composite of barnacle nauplius larval concentration.

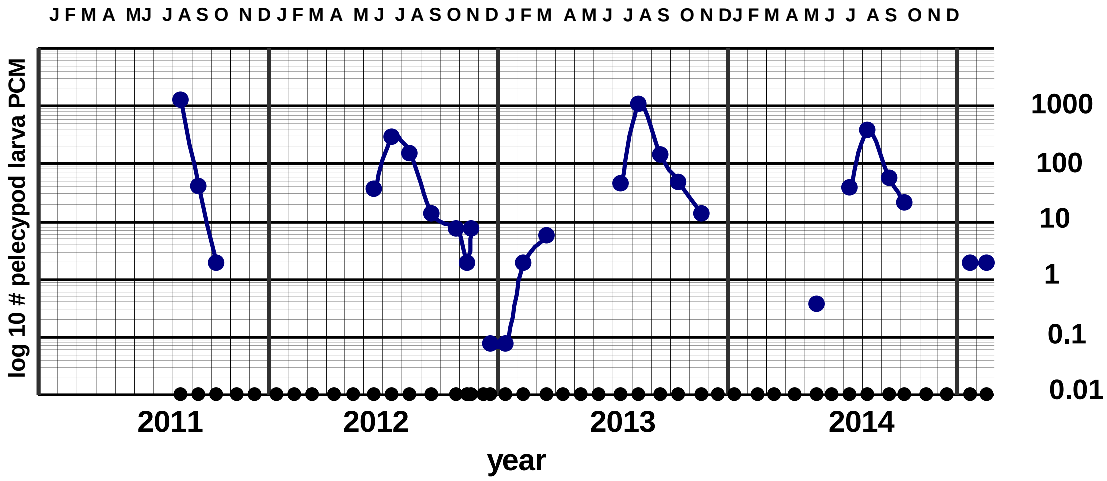


Figure 47. Bivalvia larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Peak density of one hundred to one thousand bivalve larvae per cubic meter occurred between July and August.

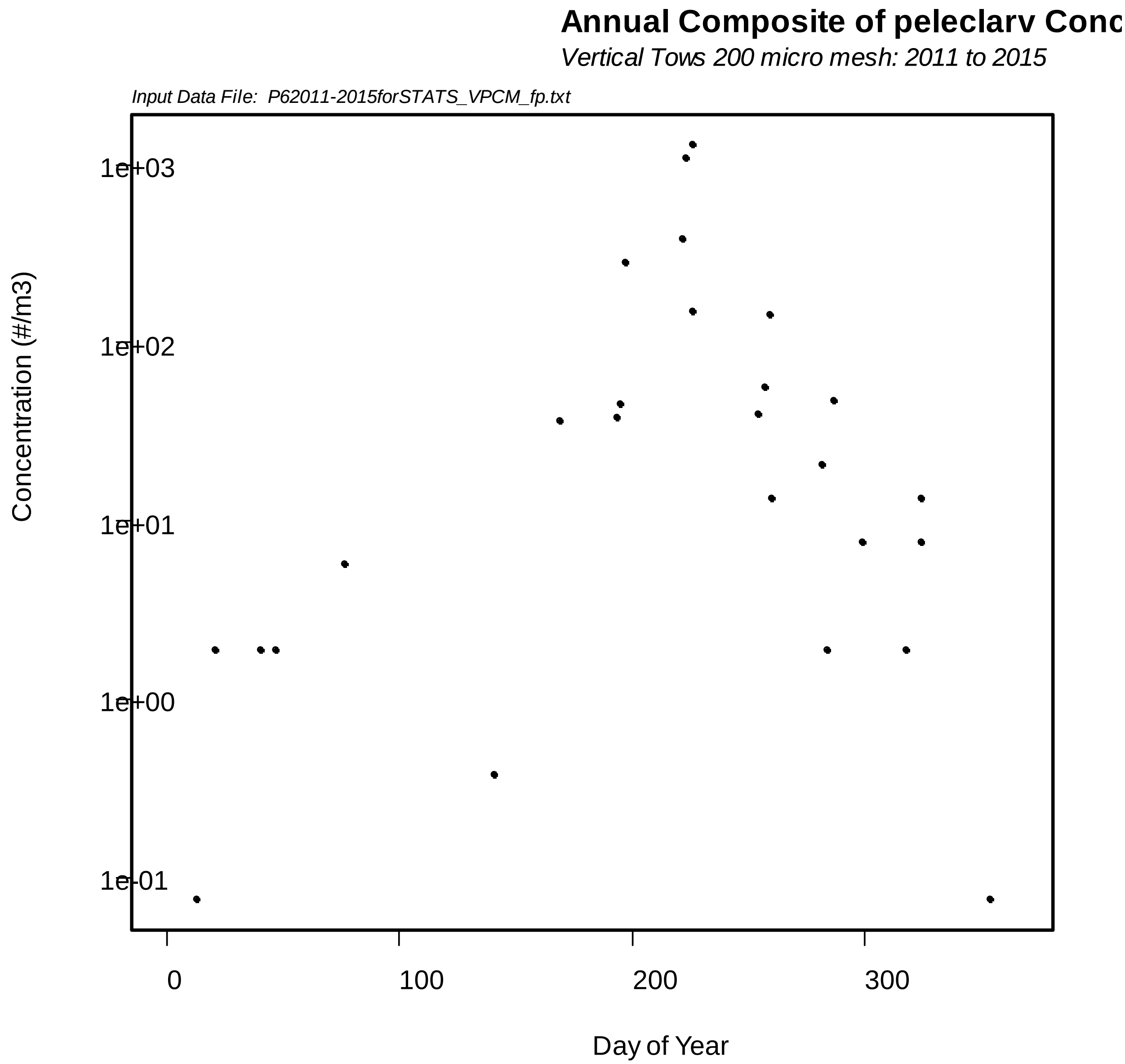


Figure 48. Annual composite of bivalve larval concentration.

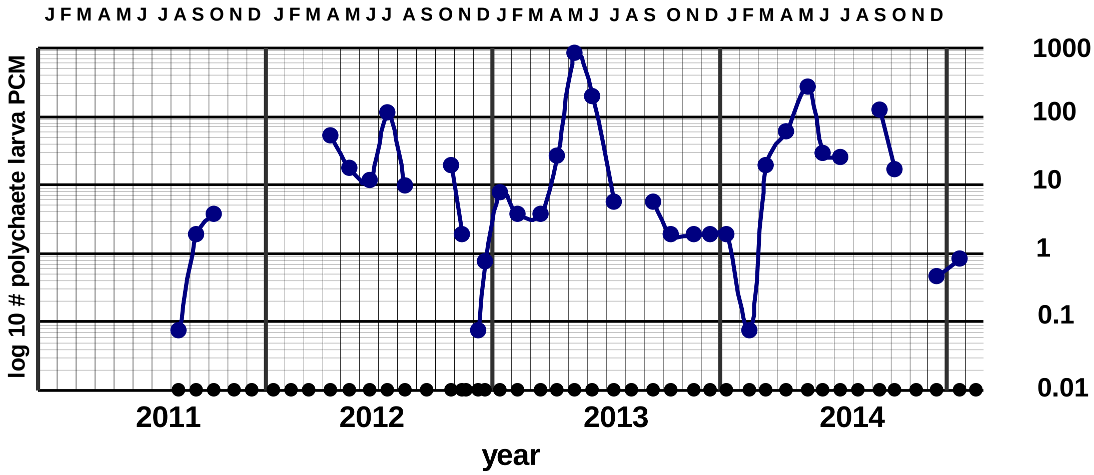


Figure 49. Polychaeta larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Polychaete larvae were present for most of the year. The highest density peak of the series approached one thousand per cubic meter in the spring of 2013. There are also spring peaks of about one hundred in 2012 and 2014.

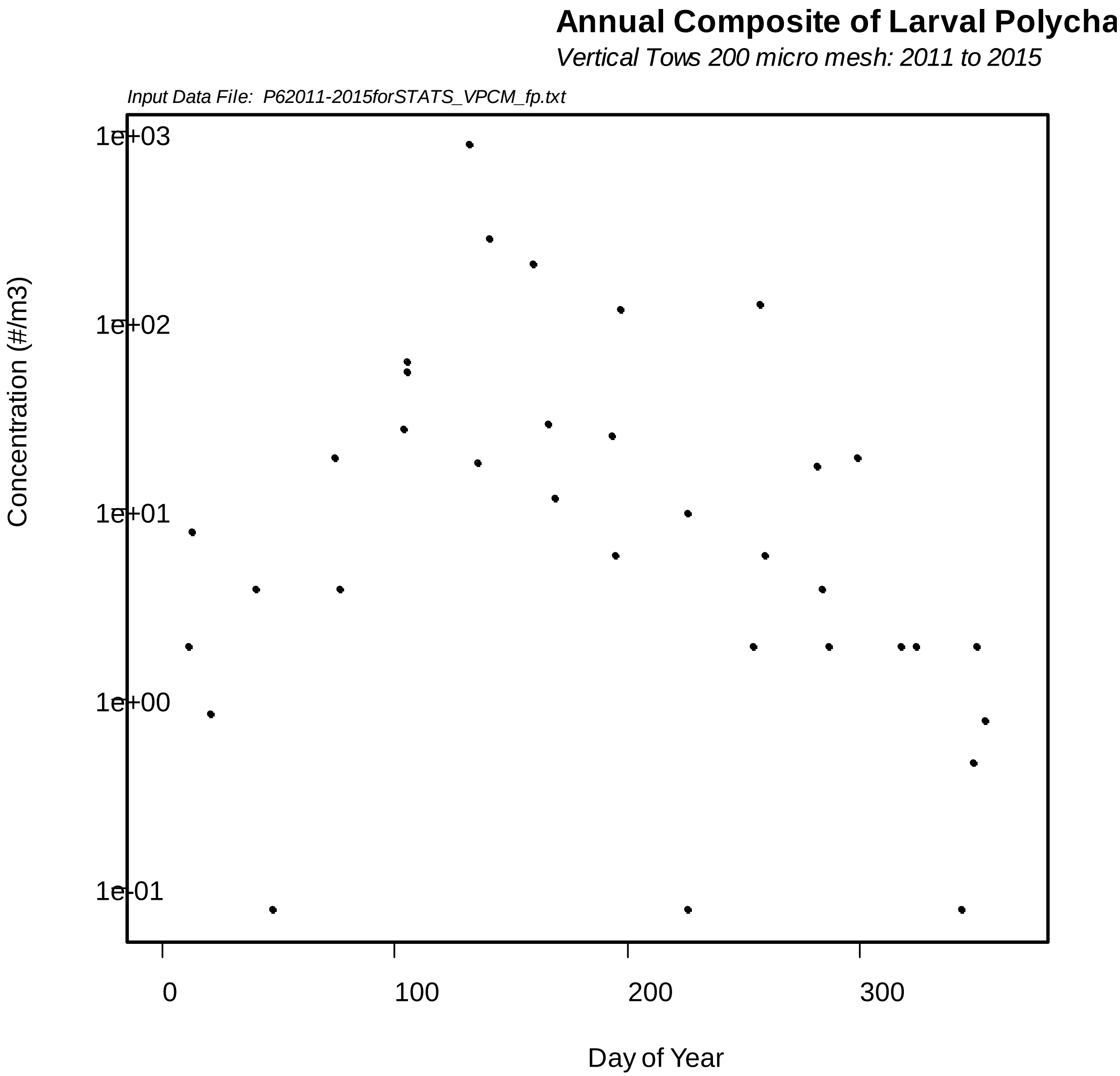


Figure 50. Annual composite of polychaete larval concentration.

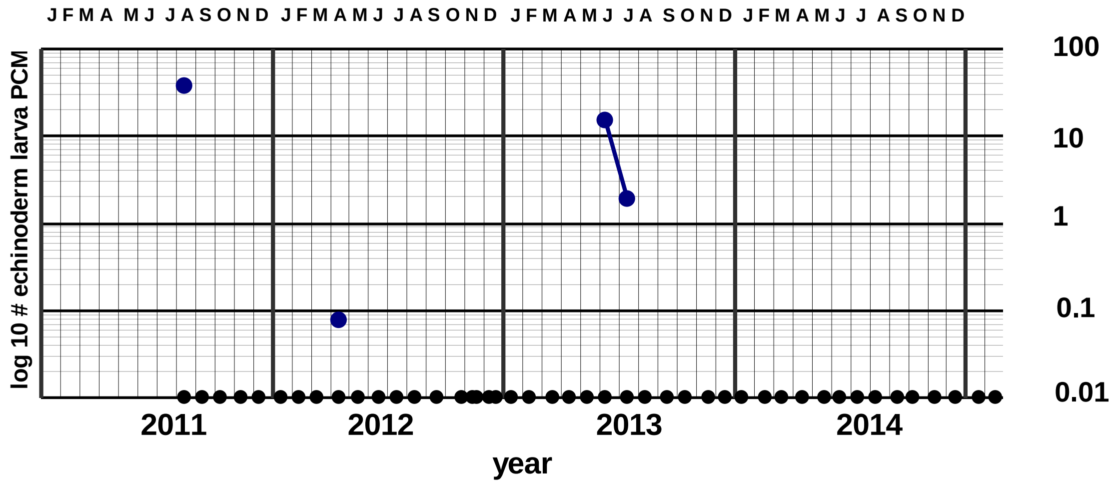


Figure 51. Echinodermata larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Echinoderm larvae were not observed in 2014. The greatest density was in August of 2011. This larva was also seen in April of 2012 and in June and July of 2013.

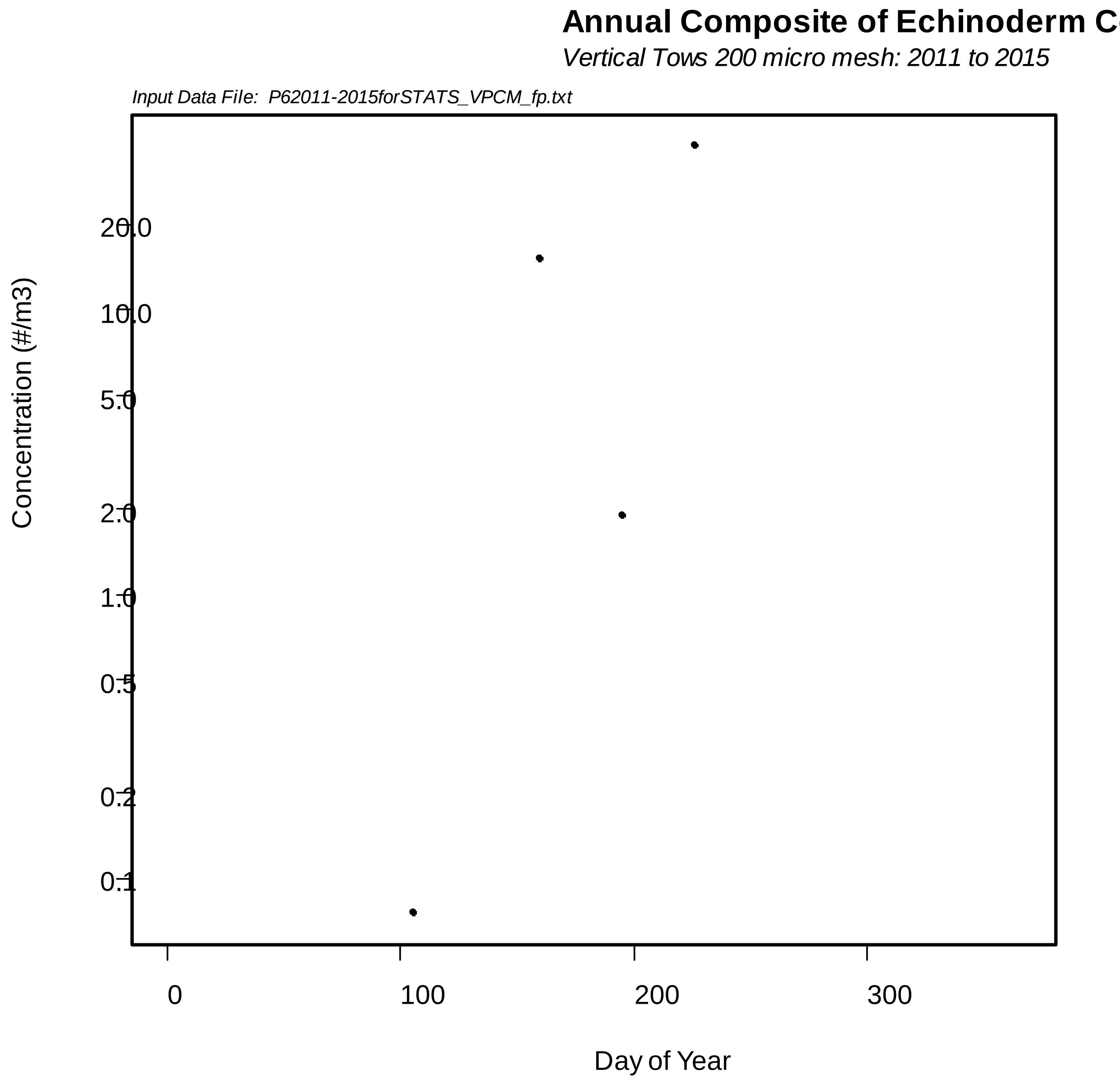


Figure 52. Annual composite of echinoderm larval concentration.

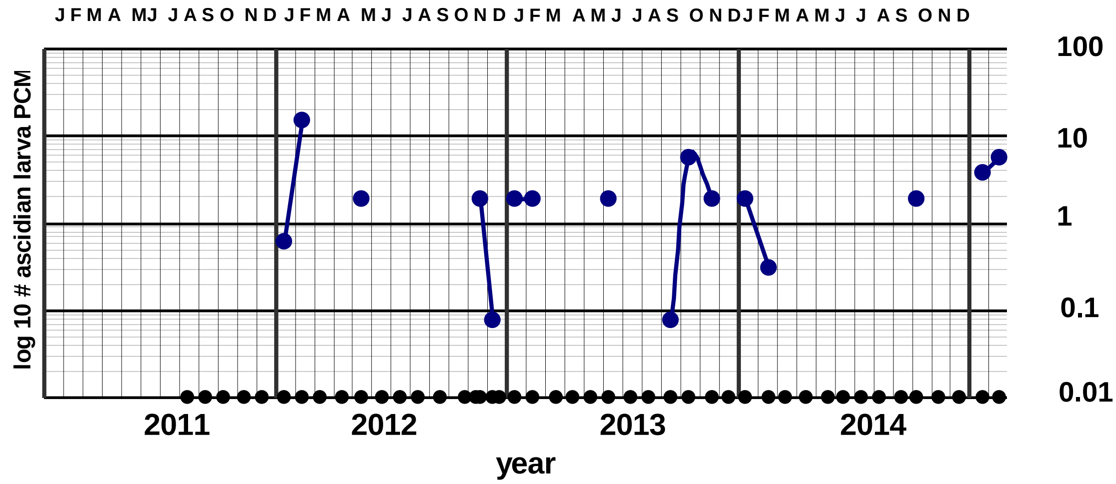


Figure 53. Ascidian larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Ascidian larvae were observed in the fall and winter seasons at densities between one-tenth and ten per cubic meter.

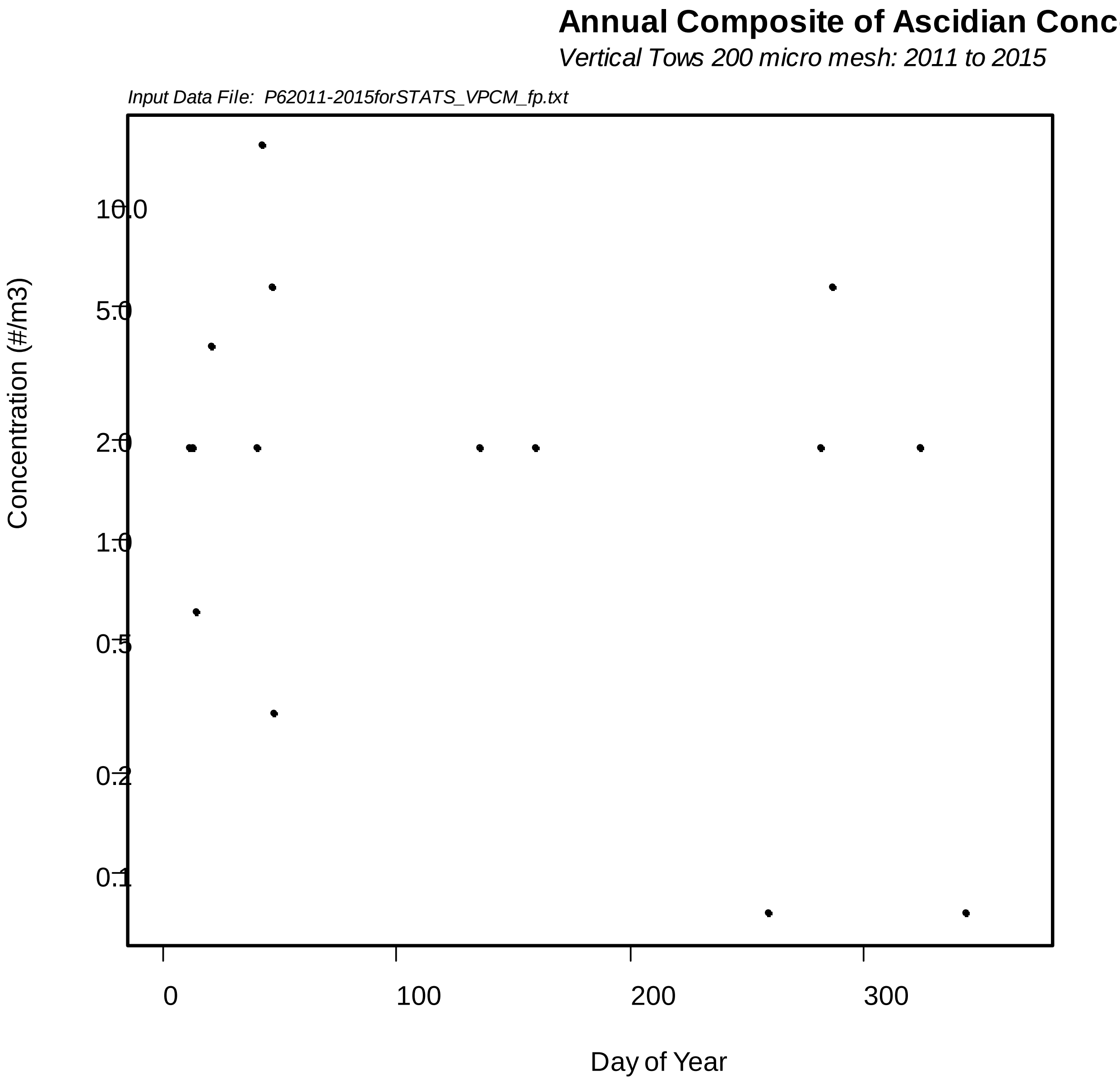


Figure 54. Annual composite of ascidian larval concentration.

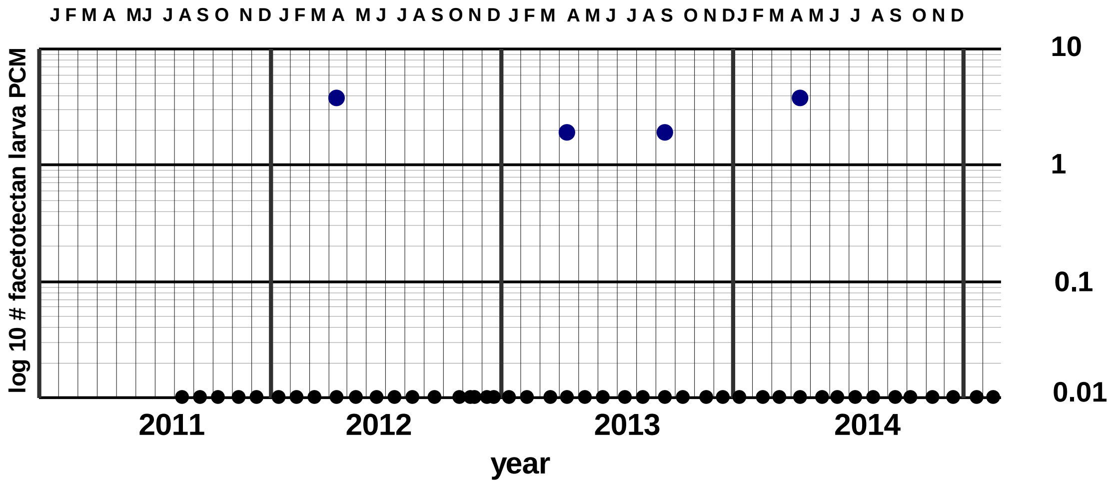


Figure 55. Facetotectan larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

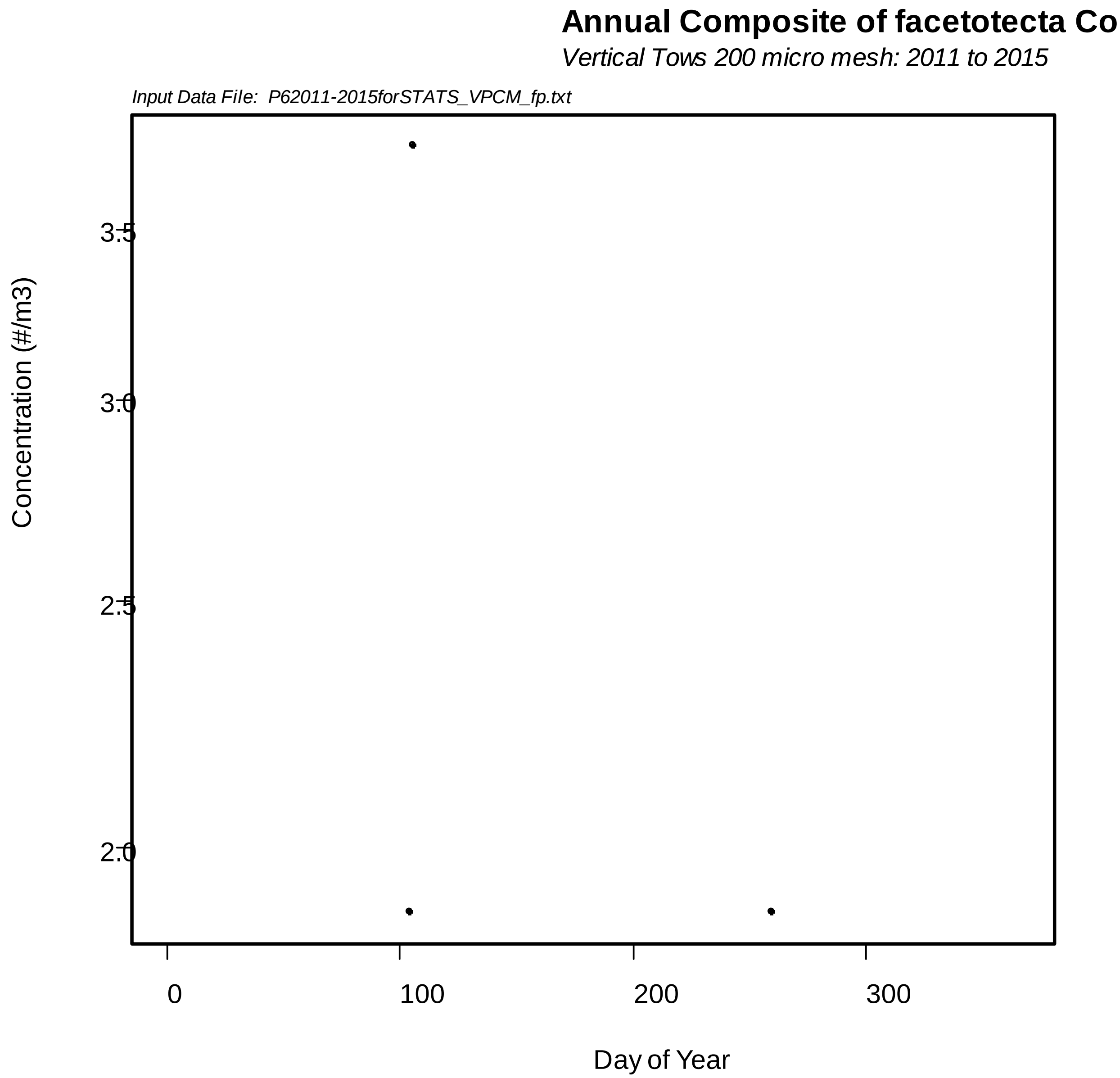


Figure 56. Annual composite of facetotectan larval concentration.

These Cirripedia are related to barnacles and are believed to parasitize other members of the Class Crustacea. They were observed in April of the past three years (2012-2014) at a density of between one and ten per cubic meter. There was also an observation in September of 2013.

Type 1 predator

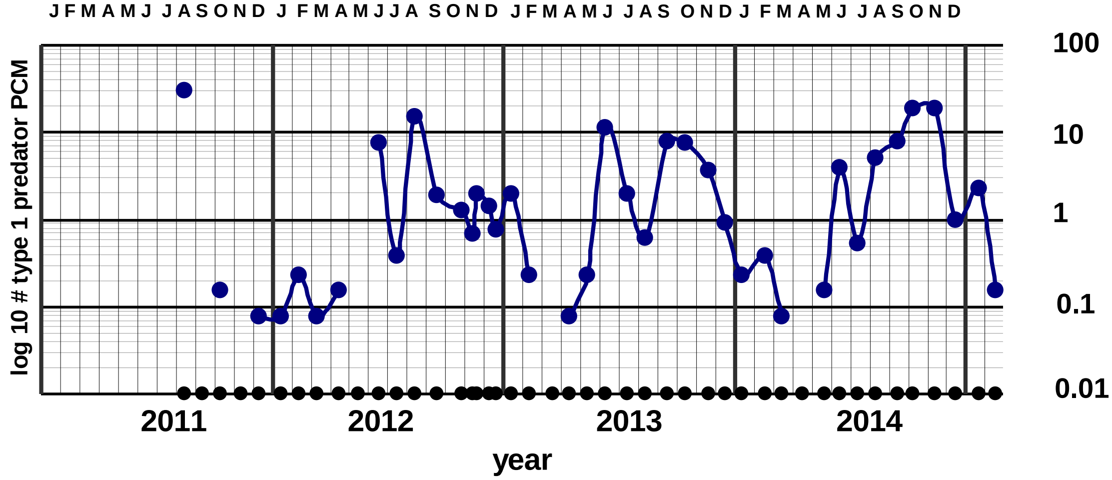


Figure 57. Type 1 predator density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot. Arrow worms are the main component of this group which includes Amphipoda, Polychaeta, Isopoda, Ostracoda and fish larvae.

Type 1 predator density exhibited June peaks in density in the tens per cubic meter. Density peaks in the fall season have been increasing; on-tenth in 2011, one in 2012, ten in 2013 and twenty in 2014.

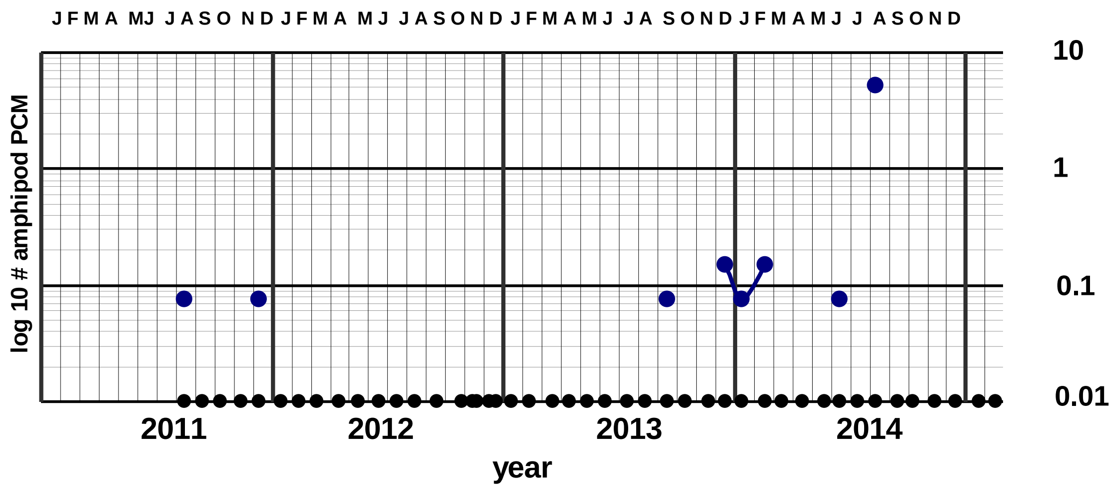


Figure 58. Amphipoda density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

There were no amphipods seen in 2012. They were seen at a low density in August and December of 2011, in September and December of 2013 and in January, February, June and August of 2014.

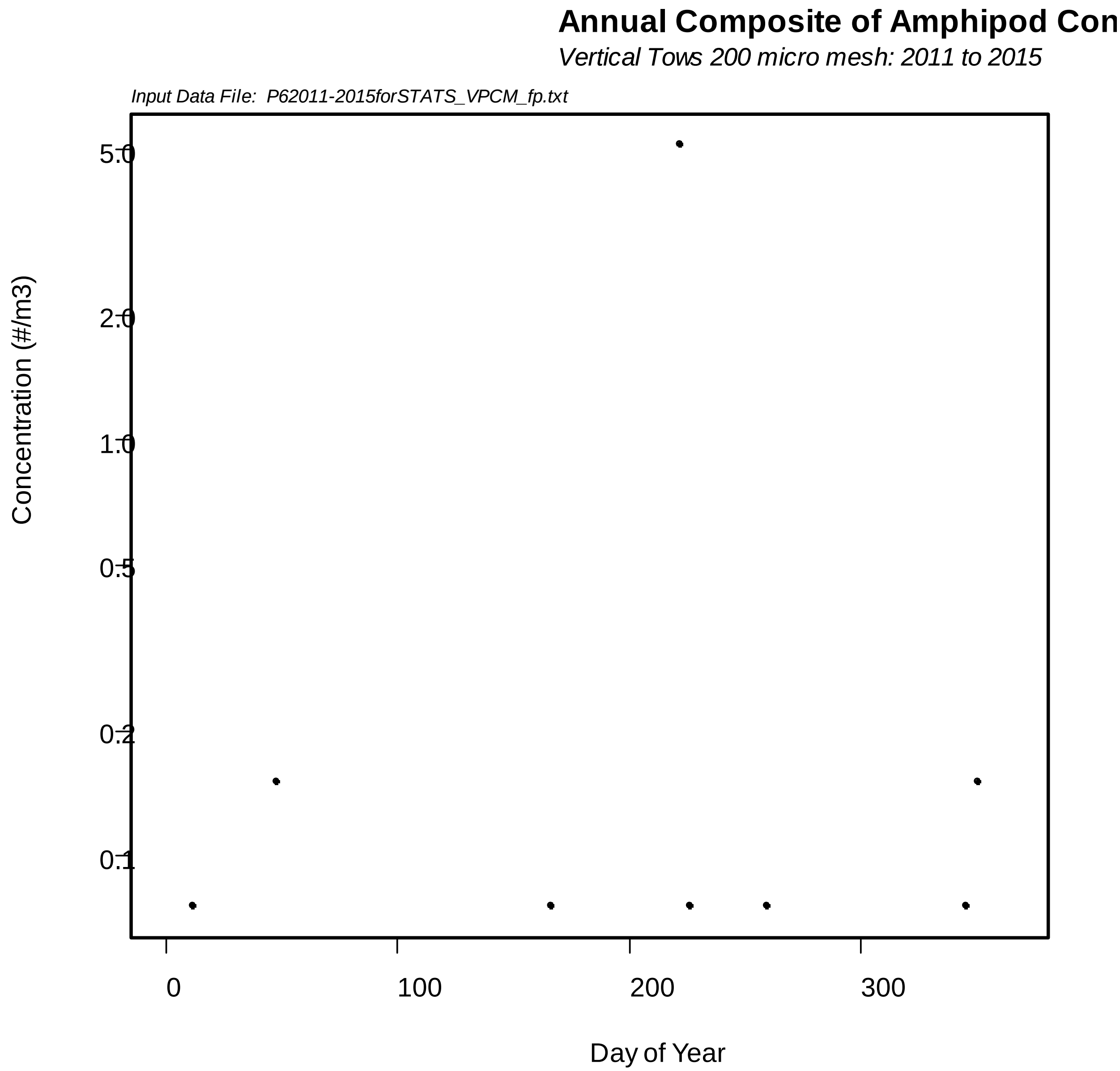


Figure 59. Annual composite of amphipod concentration.

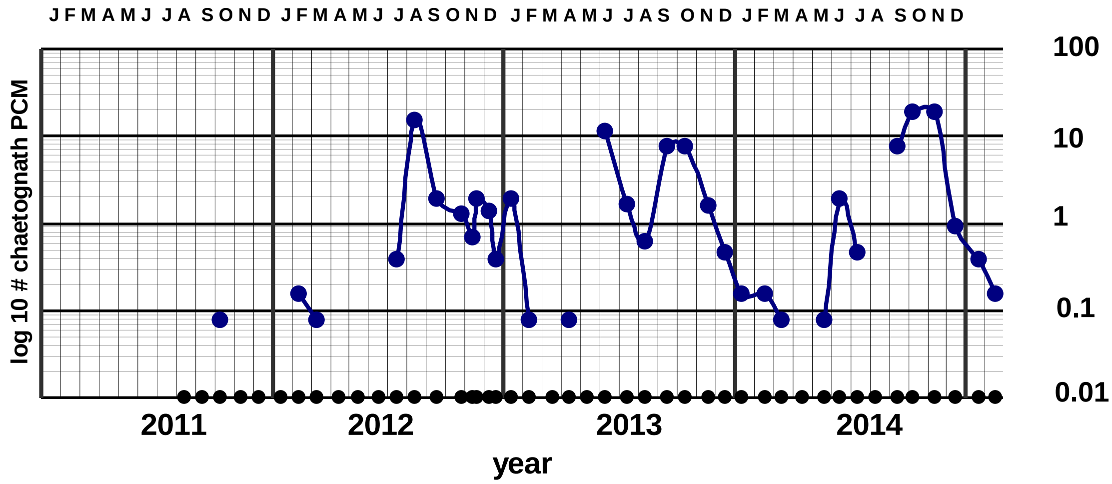


Figure 60. Chaetognatha density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

The arrow worm is mainly ***Parasagitta elegans*** with a few ***Eukronia hamata.*** Density peaks in the fall season have been increasing; one-tenth in 2011, one in 2012, ten in 2013 and twenty in 2014.

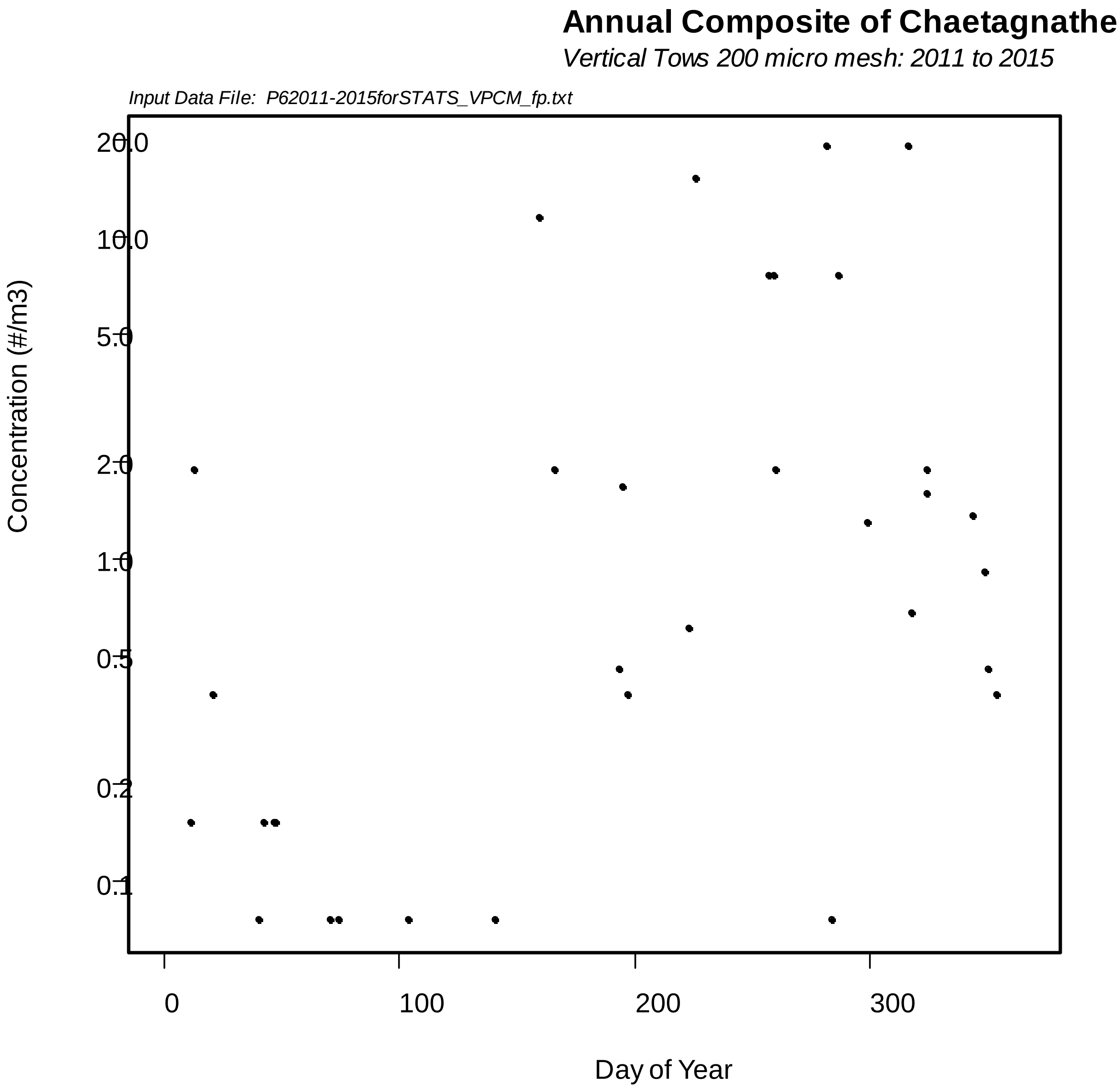


Figure 61. Annual composite of ***Parasagitta elegans*** concentration.

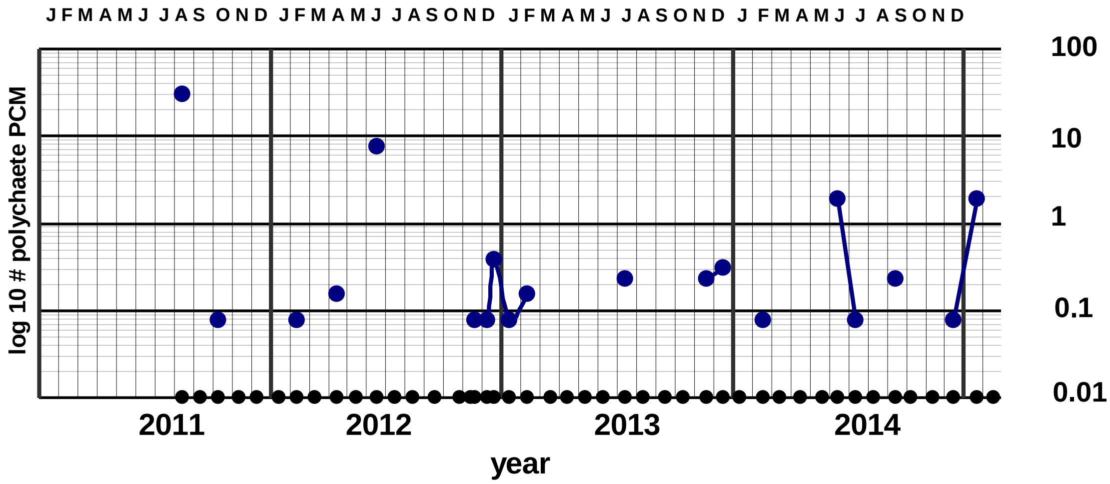


Figure 62. Polychaeta density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Polychaetes were seen for between four and six months of the year, mainly in the fall and winter seasons.

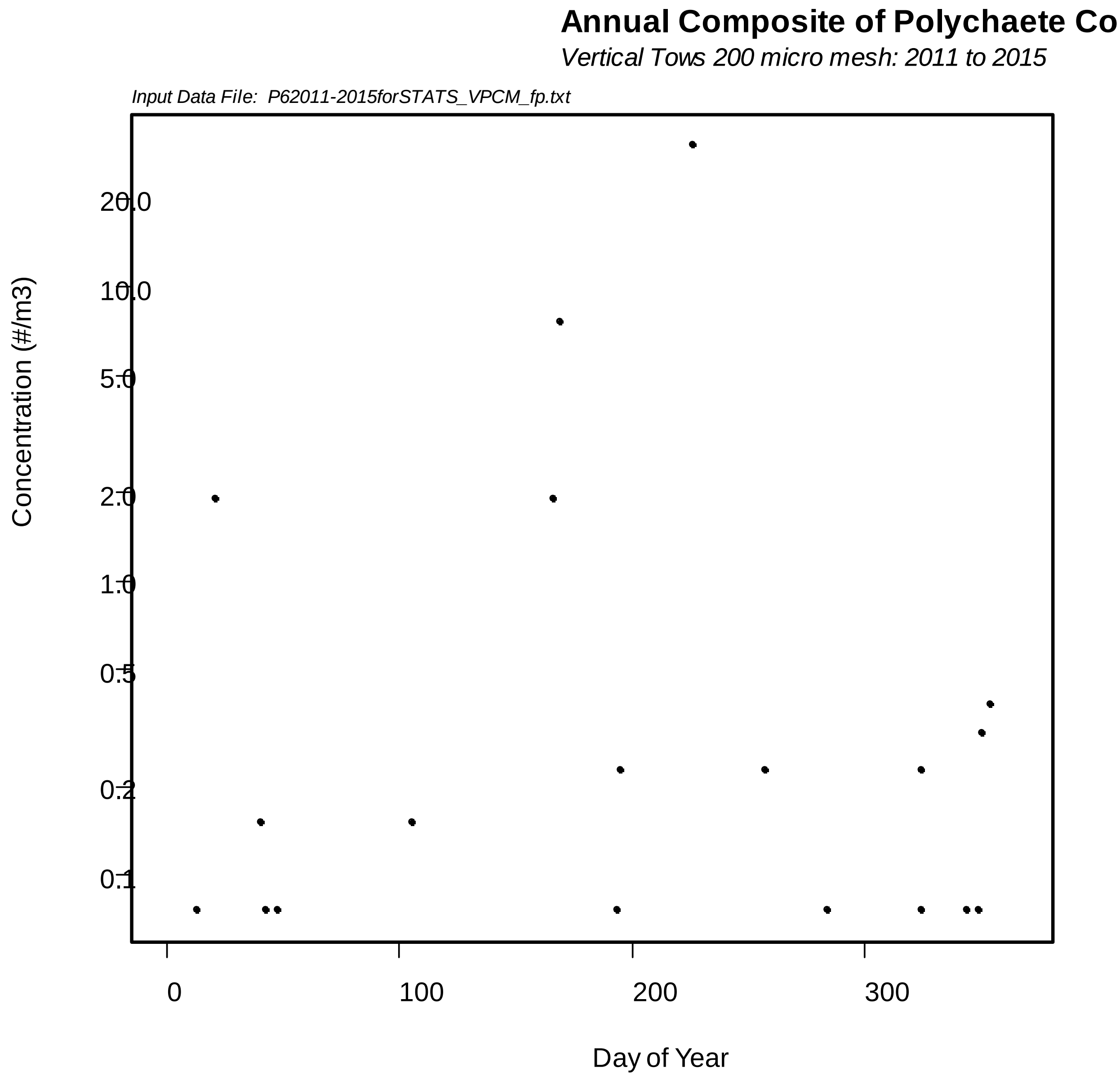


Figure 63. Annual composite of polychaete concentration.

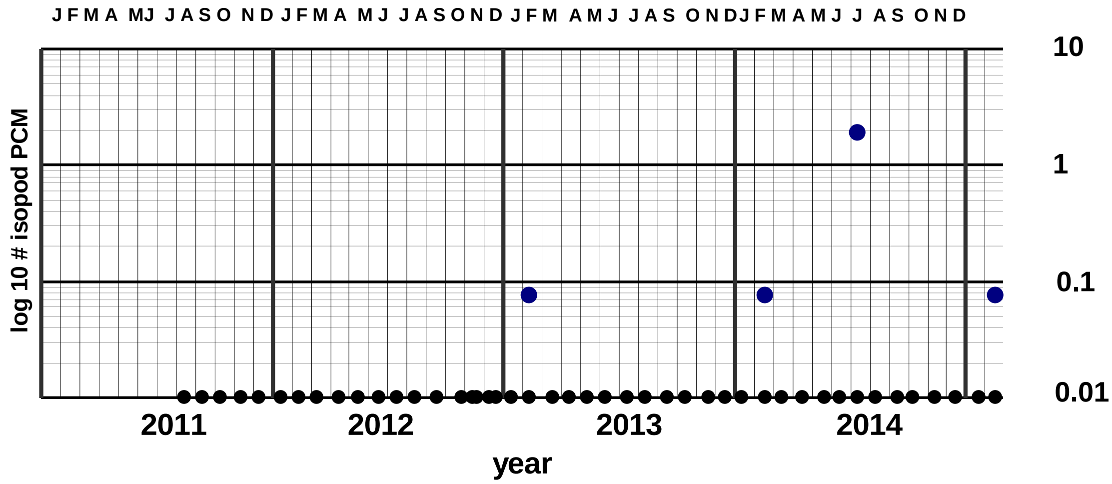


Figure 64. Isopoda density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Isopods were seen in February of 2013-2015 and at a higher density in July of 2014.

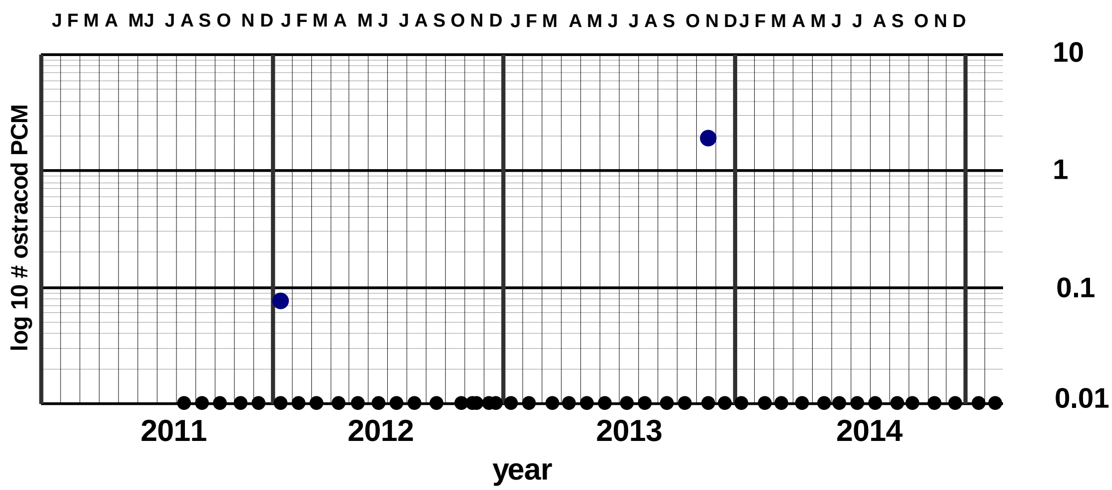


Figure 65. Ostracoda density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Ostracods were seen in January of 2012 and in November of 2013.

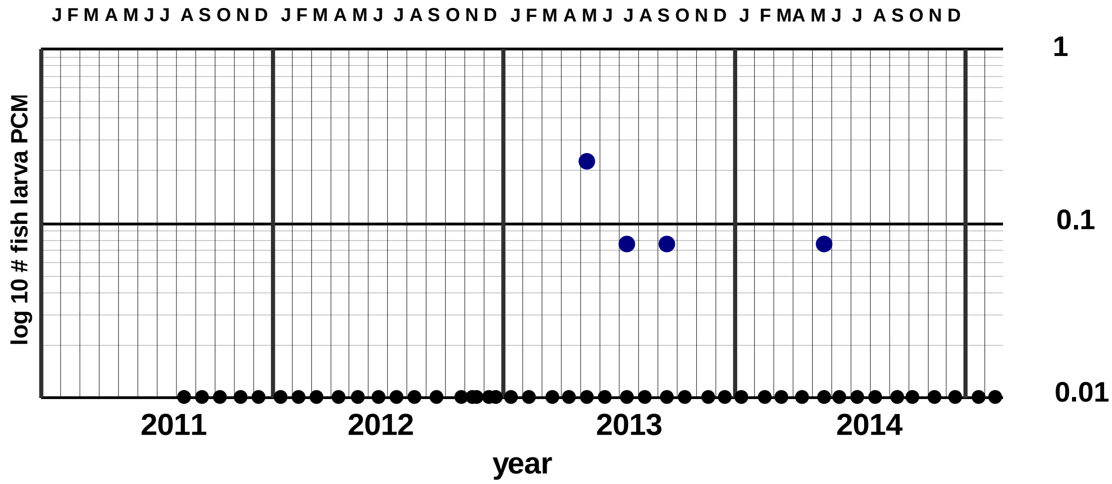


Figure 66. Fish larval density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Fish larvae were encountered only four times in the vertical haul series and three of them were in 2013; May, July and September. They were also seen in May of 2014.

Type2predator

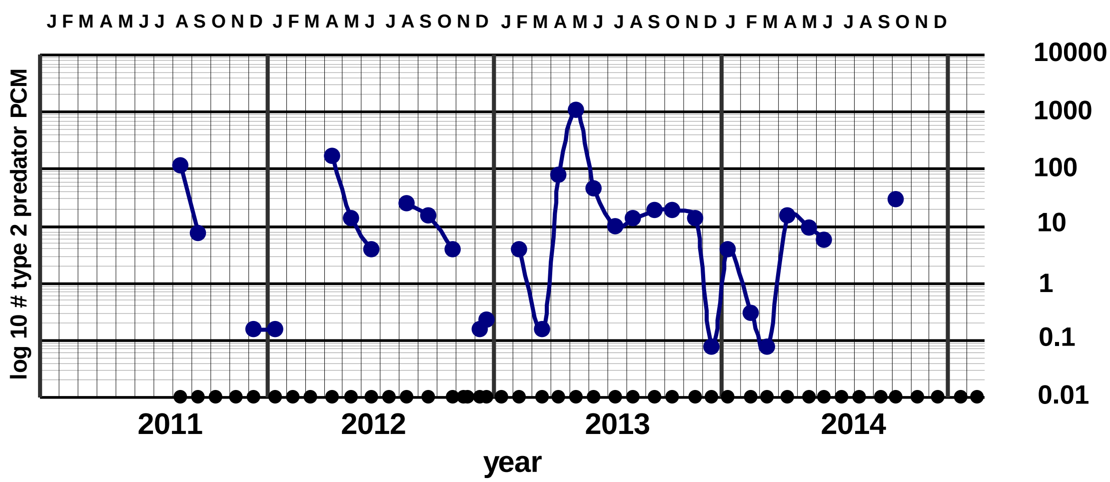
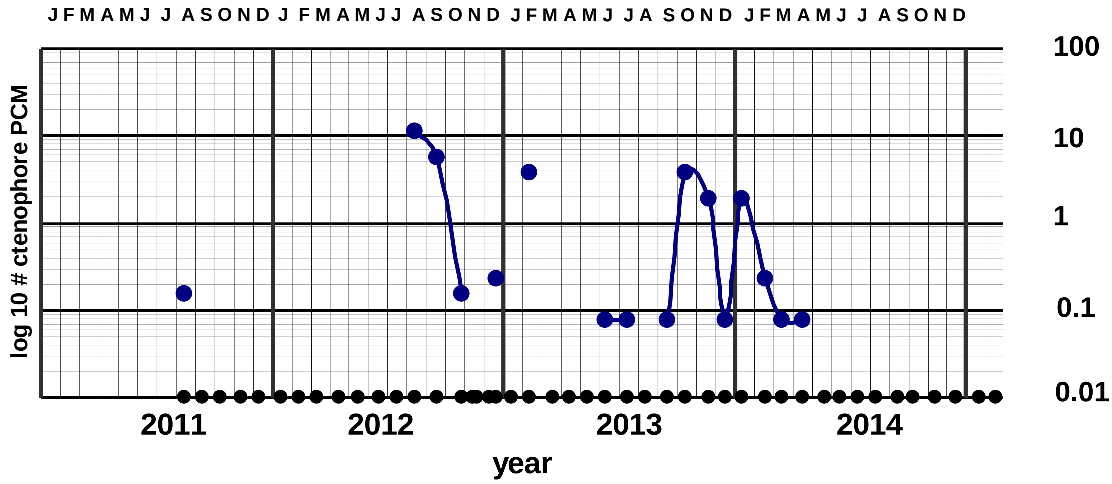


Figure 67. Type 2 predator density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot. Cnidaria are the main component of this group of jellies which also includes ctenophores.

There were increasing annual maximum densities from 2011 to 2013 which occurred in August, April and May respectively and then a smaller peak in April of 2014 and a single occurrence in October.



Figure

Figure 68. Ctenophora density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

Ctenophores were all ***Pleurobrachea pileus*** and they were only seen in August of 2011 until they were observed again in the summer and fall seasons of 2012 as well as the winter of 2013. They re-appeared in the summer of 2013 and persisted until the early spring of 2014. They have not been observed in the plankton since.

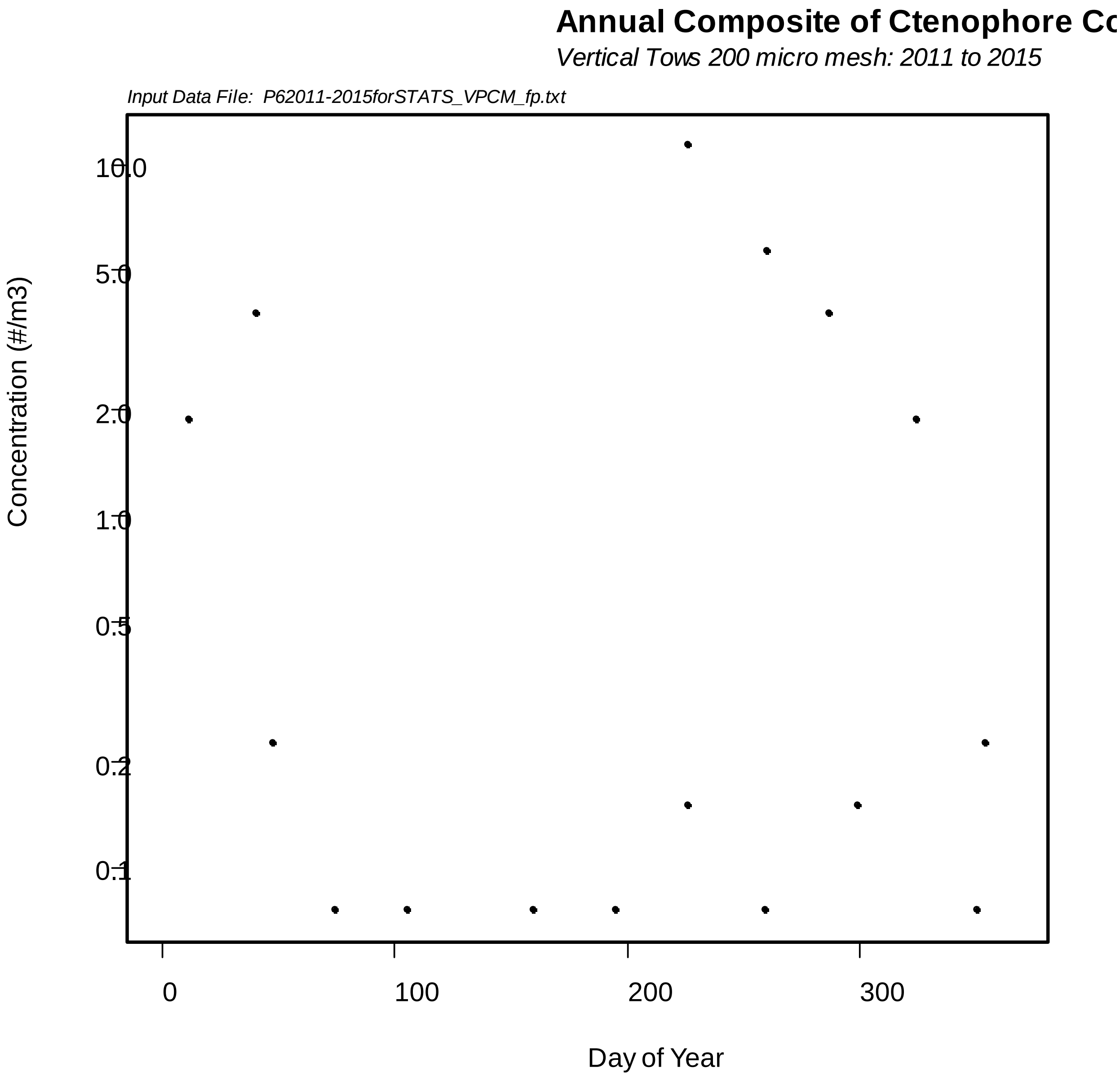


Figure 69. Annual composite of ctenophore concentration.

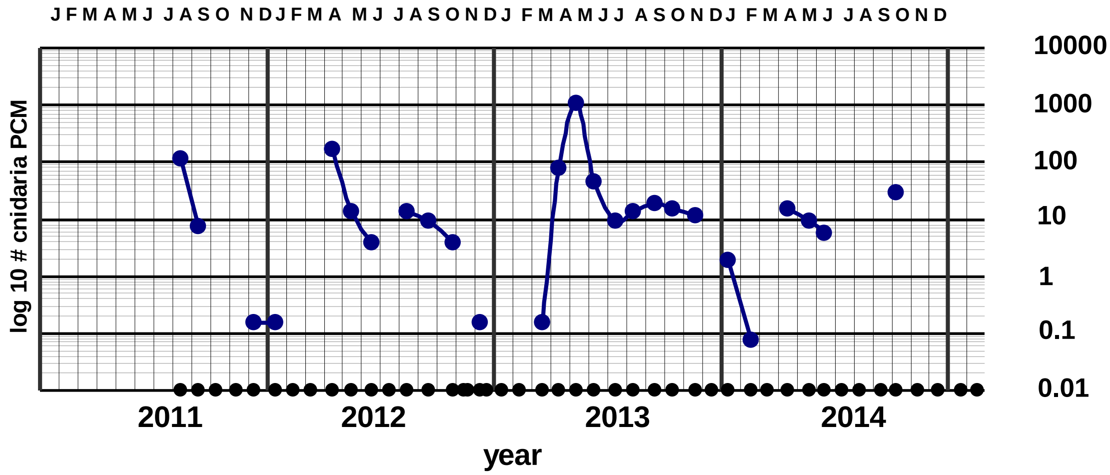


Figure 70. Cnidaria density (number per cubic meter) as estimated from fine mesh vertical plankton tow. Sampling dates are marked along the bottom of the plot.

There was a peak of Cnidaria density in August of all the years sampled. From 2011 to 2013 the peaks increased in density and the number of samples containing Cnidaria increased as well.

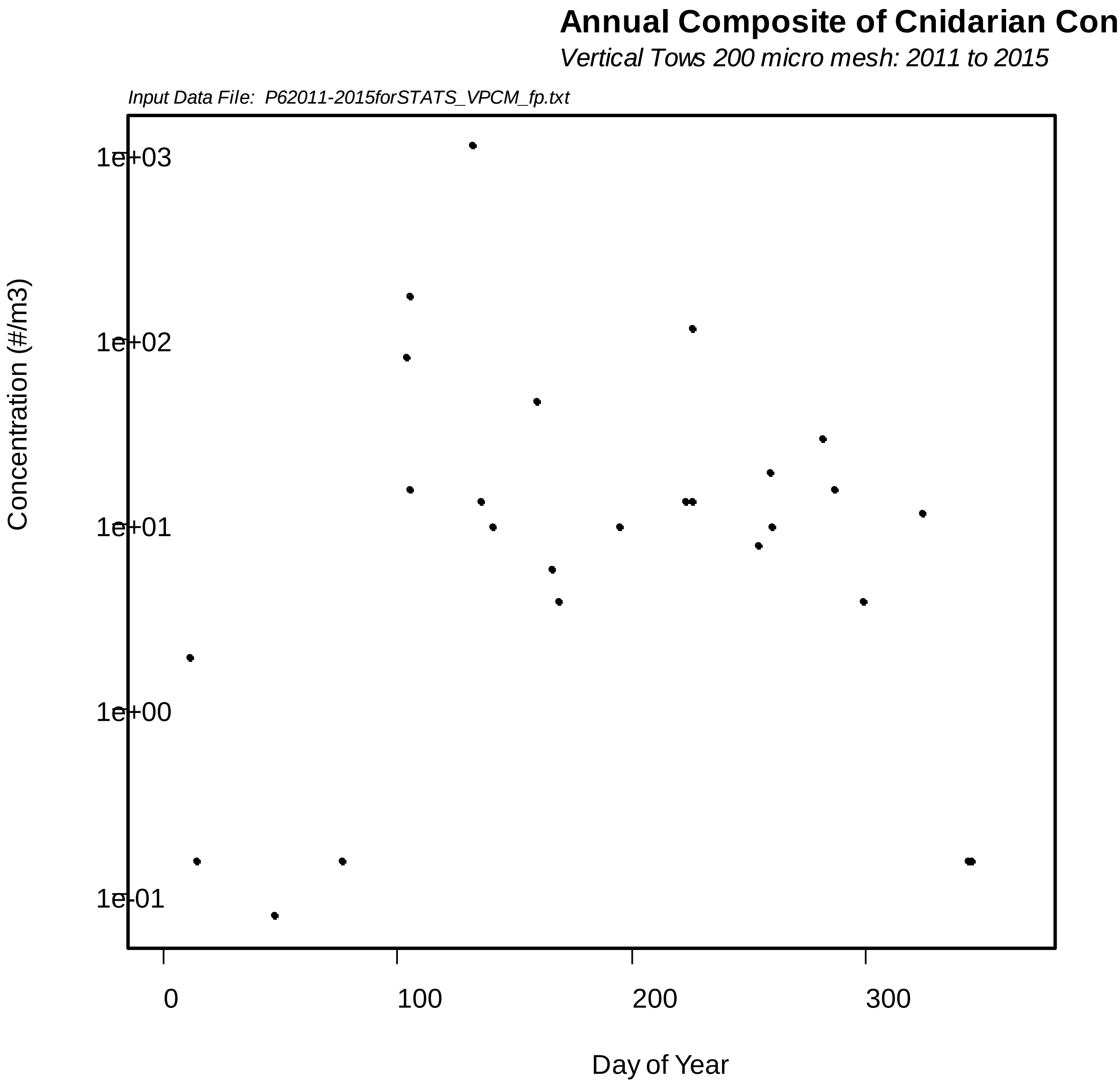


Figure 71. Annual composite of Cnidaria concentration.

Table 3. Overview of annual presence and absence of identified taxonomic categories within vertical tows from station Prince 6 between 15 August 2011 and 17 February 2015.

	Months												Number of Months Present
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	
Number of Samples	4	4	3	3	3	3	3	4	4	4	5	5	
Number of Taxa Present	18	19	16	21	19	22	24	19	27	21	20	14	
Taxa (33 total)													
Calanoid Copepoda	1	1	1	1	1	1	1	1	1	1	1	1	12
Copepoda nauplius larva	1	1	1	1	1	1	1	1	1	1	1	1	12
Polychaeta larva	1	1	1	1	1	1	1	1	1	1	1	1	12
Chaetognatha	1	1	1	1	1	1	1	1	1	1	1	1	12
Limacina helicina	1	1	1	1	1	1	1	1	1	1	1	1	12
Cnidaria	1	1	1	1	1	1	1	1	1	1	1	1	12
Cirripedia nauplius	1	1	1	1	1	1	1	1	1	1	1	1	12
Invertebrate egg	1	1	1	1	1	1	1	1	1	1	1		11
Ctenophora	1	1	1	1		1	1	1	1	1	1	1	11
Decapoda larva	1	1	1	1	1	1	1	1	1	1	1		11
Oikopleura labradoriensis	1	1	1	1	1	1	1	1	1	1	1		11
Calanus sp.	1	1	1	1	1	1	1		1	1	1	1	11
Bivalvia larva	1	1	1		1	1	1	1	1	1	1	1	11
Polychaeta	1	1		1		1	1	1	1	1	1	1	10
(fish) Aplousobranchia larva	1	1			1	1			1	1	1	1	8
Cladocera				1	1	1	1	1	1	1	1		8
Euphausiacea furcilia		1	1	1	1		1	1	1	1			8
Fish eggs				1	1	1	1	1	1	1			7
Harpacticoid Copepoda	1		1	1	1	1	1		1				7
Cirripedia cypris		1		1	1	1	1		1	1			7
Amphipoda	1	1				1		1	1			1	6
Euphausiidae nauplius						1	1		1	1			4
Euphausiidae calyptopis							1	1	1	1			4
Echinodermata				1		1	1	1					4
fish			1						1		1		3
Fish larva					1		1		1				3
Isopoda		1					1						2
Lepeophtheirus salmonis											1	1	2
Ostracoda	1										1		2
Facetotecta				1					1				2
Euphausiidae											1		1
Mysinea													1
Cumacea													1

Fine mesh subsurface plankton tow monthly time series: August 2011 – February 2015

In these graphs the time series of density (number per cubic meter) of more than two dozen zooplankton taxa have been put into functional groups, eggs and larvae. Dots on the abscissa mark sampling dates. November of 2012 was sampled twice.

This net samples small copepods such as ***Acartia sp.*** and larvae that when small like early barnacle nauplius larvae would be missed by the coarse mesh net.

Setal feeders	Calanoid Copepoda Euphausiidae Mysinae Cladocera Cumacea
Mucous feeders	shelled Pteropoda Larvacea
Eggs	invertebrate fish
Larvae	Copepoda parasitic Copepoda Decapoda Euphausiidae Cirripediae parasitic Cirripedia Bivalvia Polychaeta ascidian Echinodermata
Type 1 predator– raptorial	Amphipoda Chaetognatha Polychaeta Isopoda Ostracoda fish larva
Type 2 predator- entangling gelatinous	tentacled Ctenophora

Cnidaria

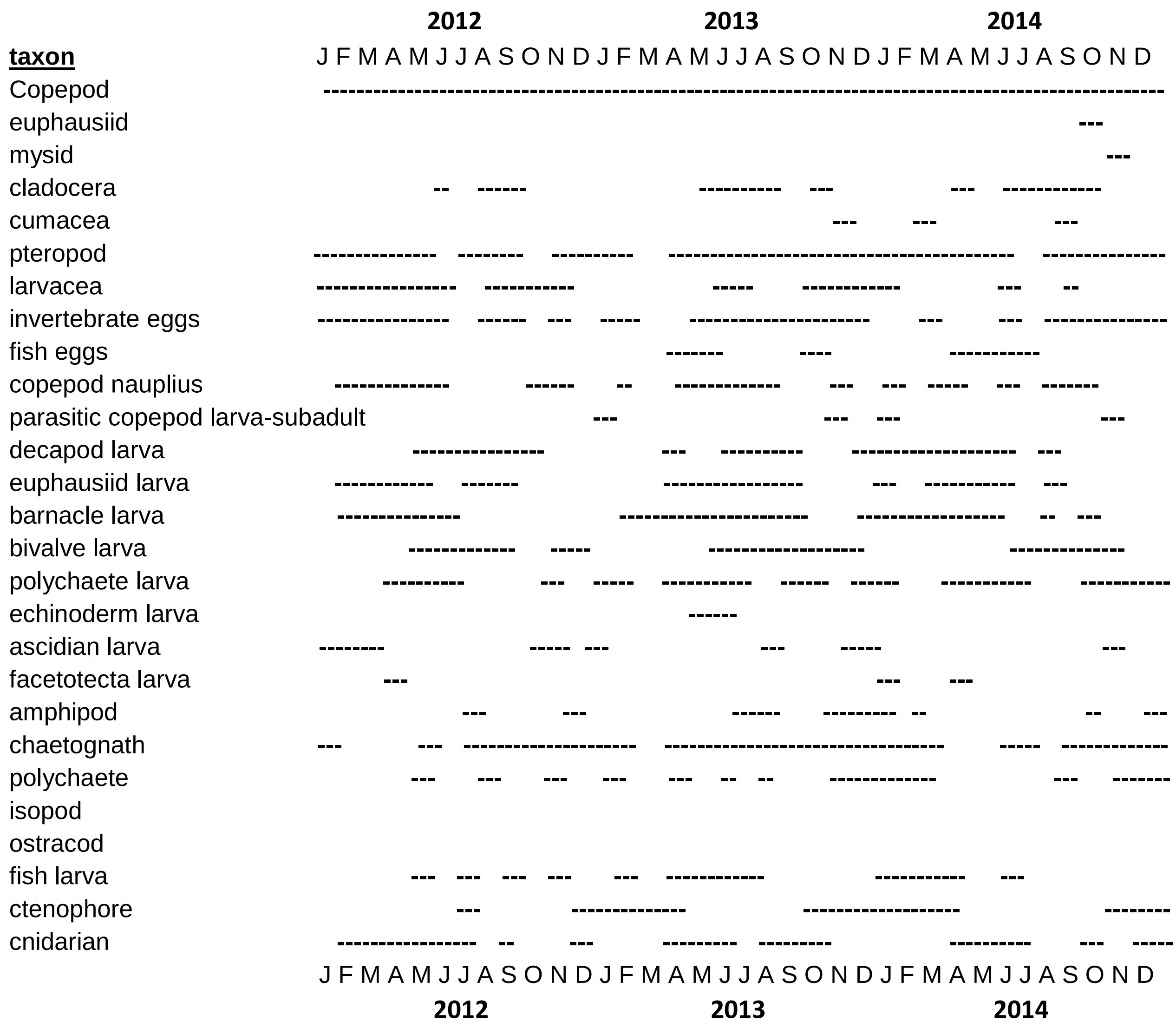


Figure 72. Presence absence over three years of several zooplankton taxa and eggs from fine mesh subsurface plankton tow series at station Prince 6.

Setal feeders

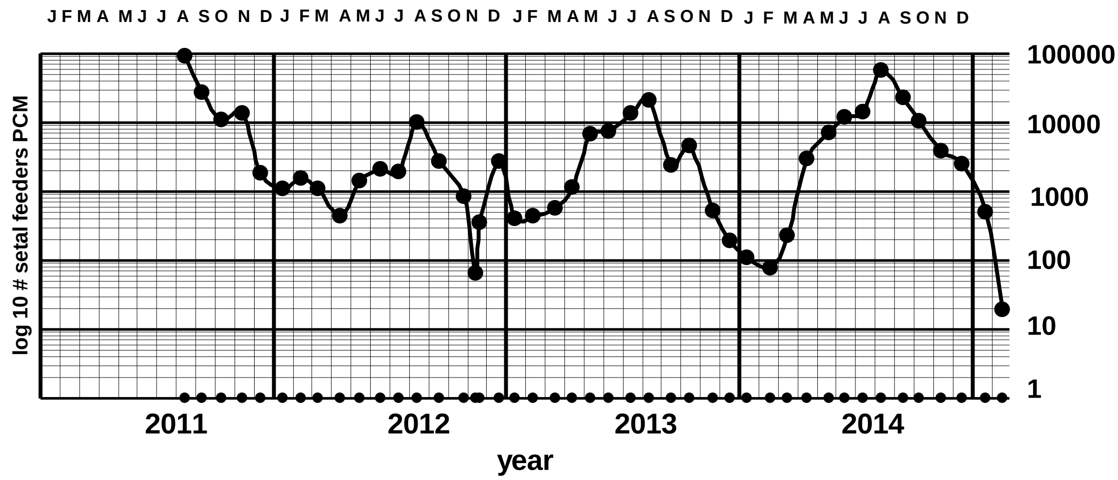


Figure 73. Setal feeding plankton density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Copepods are the main component which also includes Euphausiacea, Mysinae, Cladocera and Cumacea.

There was a peak in density of plankton that use setae for feeding in August of all years. The highest peak was in 2011. Since 2012 the peak density of setal feeders has increased steadily.

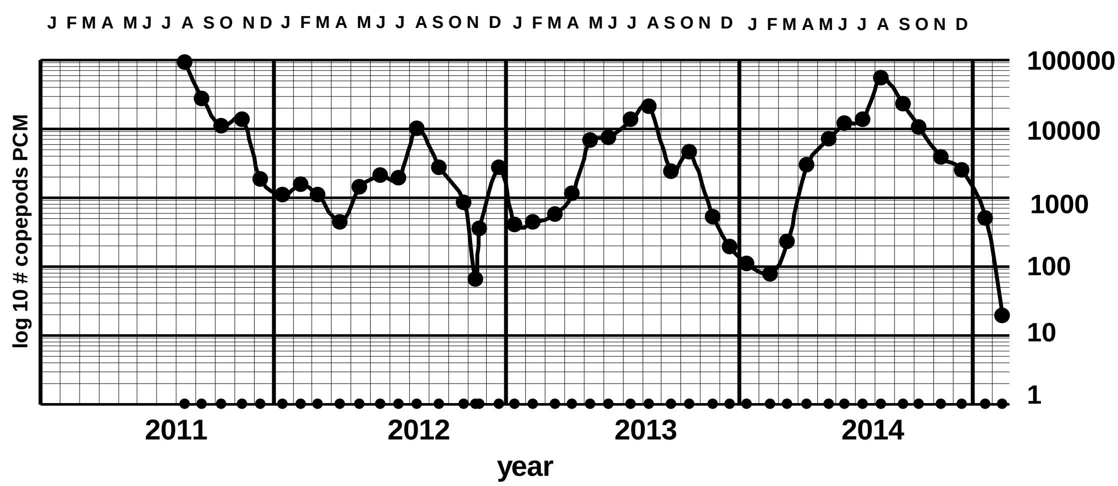


Figure 74. Calanoid Copepoda density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

In 2011 copepod density decreased from a summer season high of about one hundred thousand per cubic meter to about one thousand per cubic meter by winter. In 2012 copepod density slowly increased from one thousand to ten thousand by August and then quickly declined to about one hundred by early November and then recovered to a few thousand by December. In 2013 there was a steady increase from a few hundred to twenty thousand by August followed by a rapid decline to a couple of hundred. In 2014 the decline continued for two months to less than a hundred and then increased rapidly over the following six months to a high of more than fifty thousand in August. This was followed by a rapid decline over the next six months to a record low of about eleven per cubic meter.

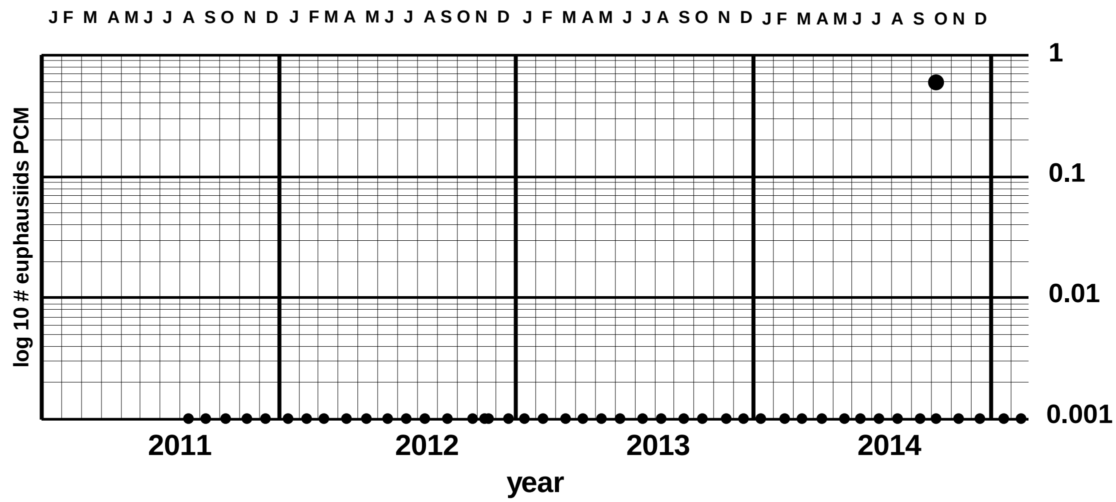


Figure 75. Euphausiidae density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

The only euphausiid sampled so far with this net was in October, 2014.

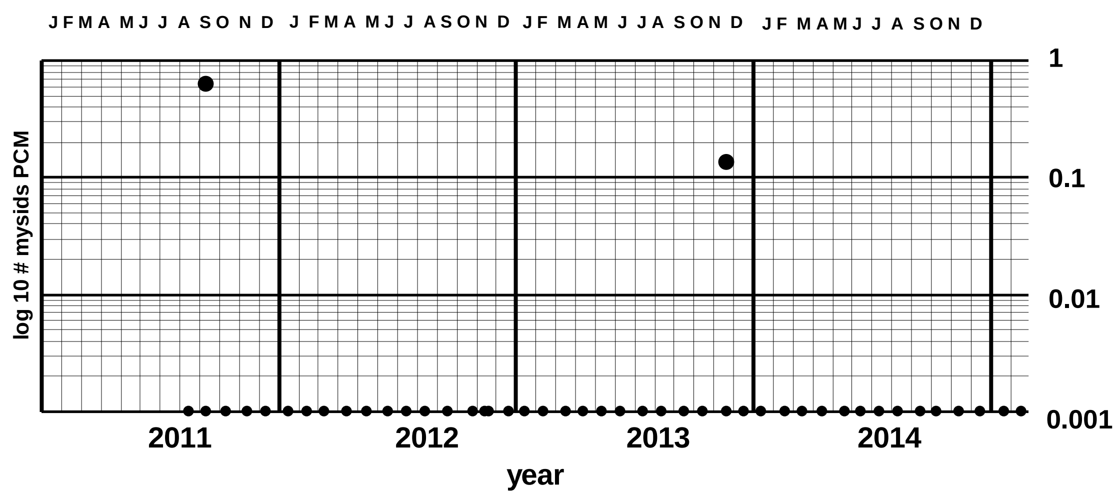


Figure 76. Mysinae density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There were two observations of mysids, one in September 2011 and another in November 2013. Samples from the deep net contained mysids at least once in a year and as many as four times between 2011 and 2014.

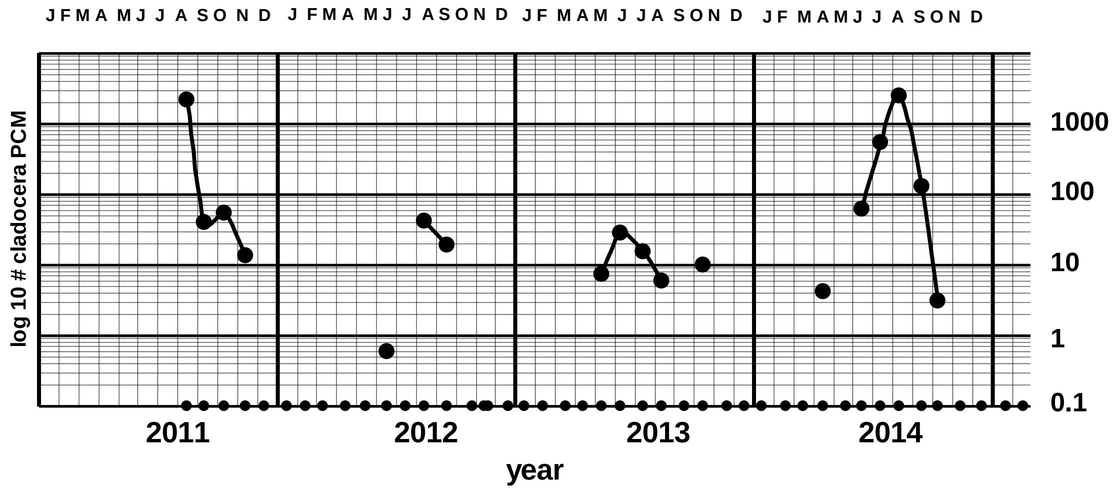


Figure 77. Cladocera density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Highest densities of tens to thousands were seen in June of 2013 and in August of the other three years.

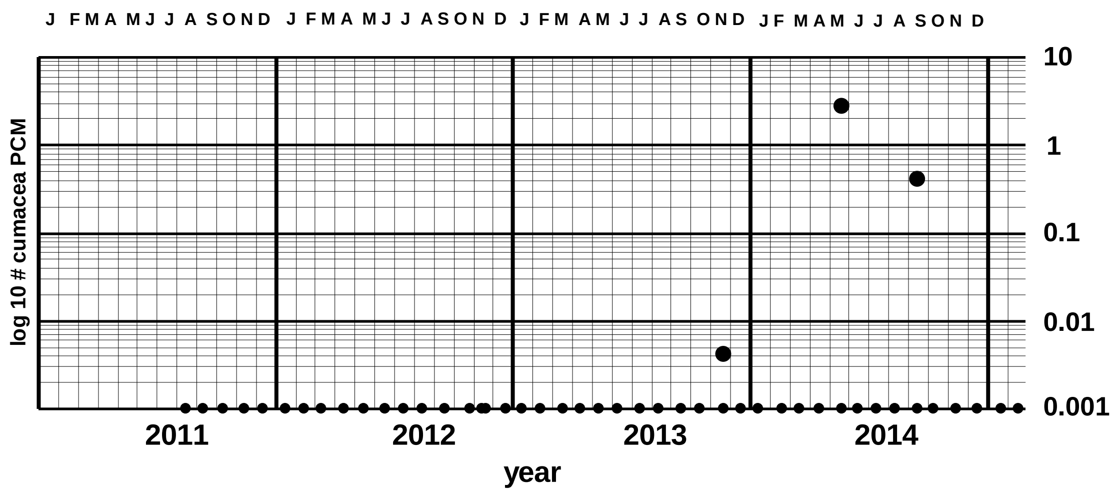


Figure 78. Cumacea density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Cumacea were not seen until November, 2013 and then again in March and September, 2014.

Mucous feeders

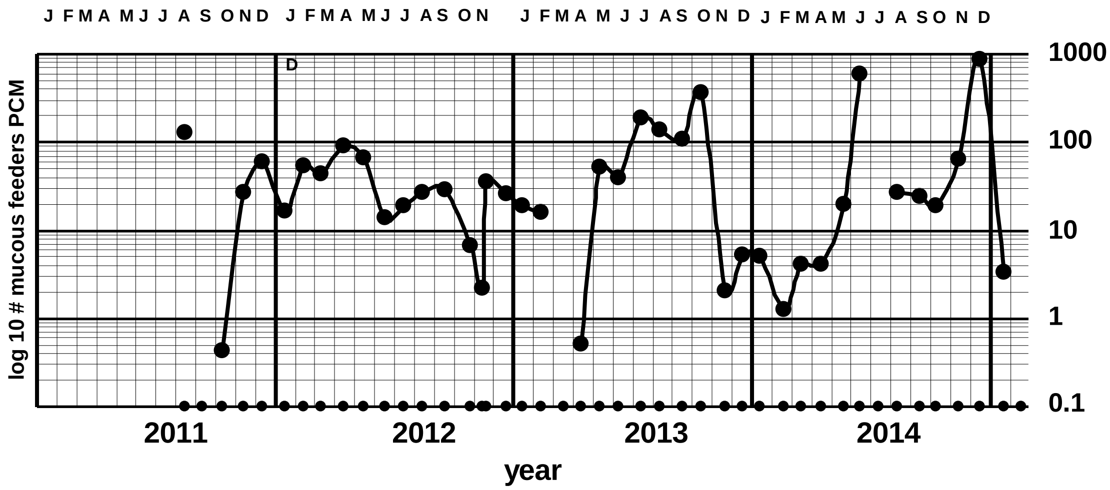


Figure 79. Mucous feeding plankton density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Pteropoda and Larvacea make up this group.

Mucous feeder density maxima were observed in the summer of 2011, in all seasons of 2012, in the summer and fall seasons of 2013, and in late spring and late fall of 2014. There has been a gradual trend of increasing density of mucous feeders since the summer of 2011.

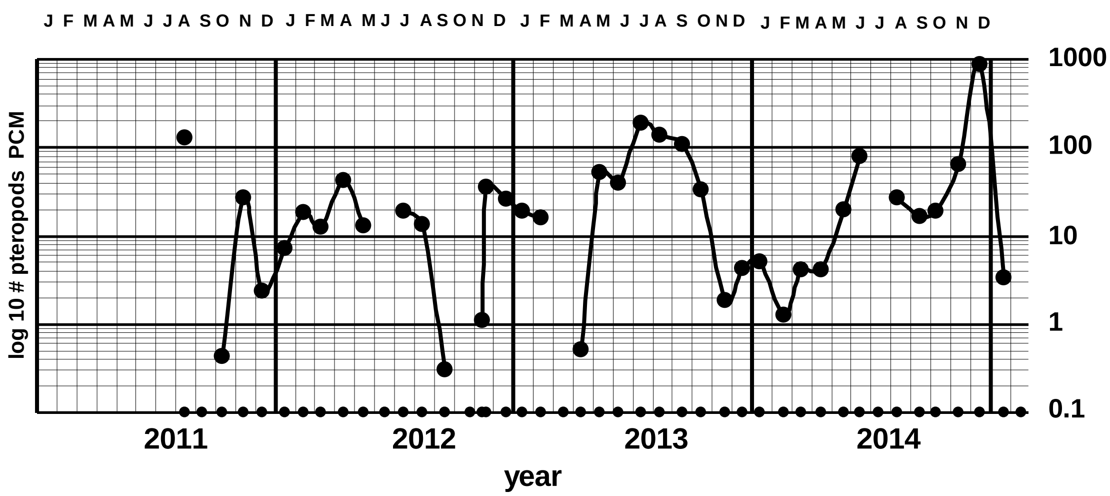


Figure 80. Pteropoda density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Pteropod density maxima were observed in the mid-summer and mid-fall of 2011, in the spring and fall of 2012, in the early summer of 2013, and in late spring and late fall of 2014. There has been a gradual trend of increasing density of pteropods since the summer of 2011.

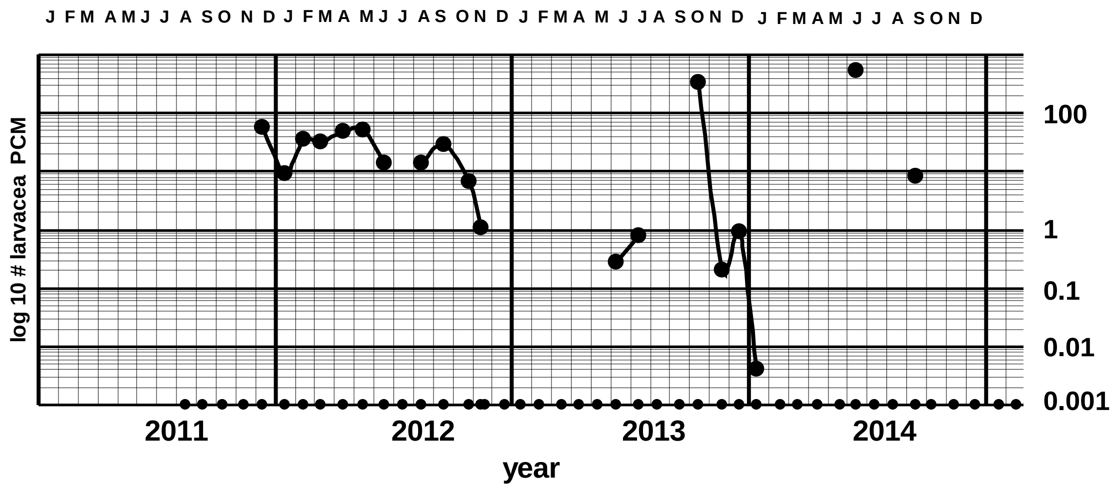


Figure 81. Larvacea density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Larvacea were found until mid-fall of 2012 and none were seen until late in the spring of 2013. The peak density in 2013 occurred in the fall season. Larvacea have been seen progressively less frequently since 2012 but when seen, the density has been gradually increasing.

Eggs

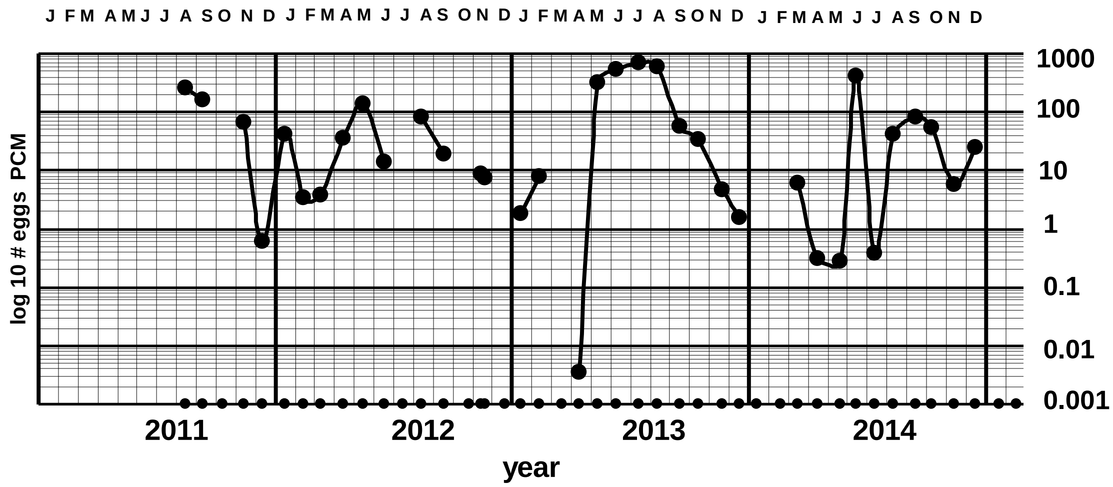


Figure 82. Egg density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. This includes the eggs of fish and of invertebrates.

Between the summer season of 2011 and the fall of 2014 egg density had not changed a lot. Density equal to or greater than one hundred per cubic meter was observed in the summer season of 2011, in the spring and summer of 2012, in the spring and summer of 2013, and in the spring and fall of 2014.

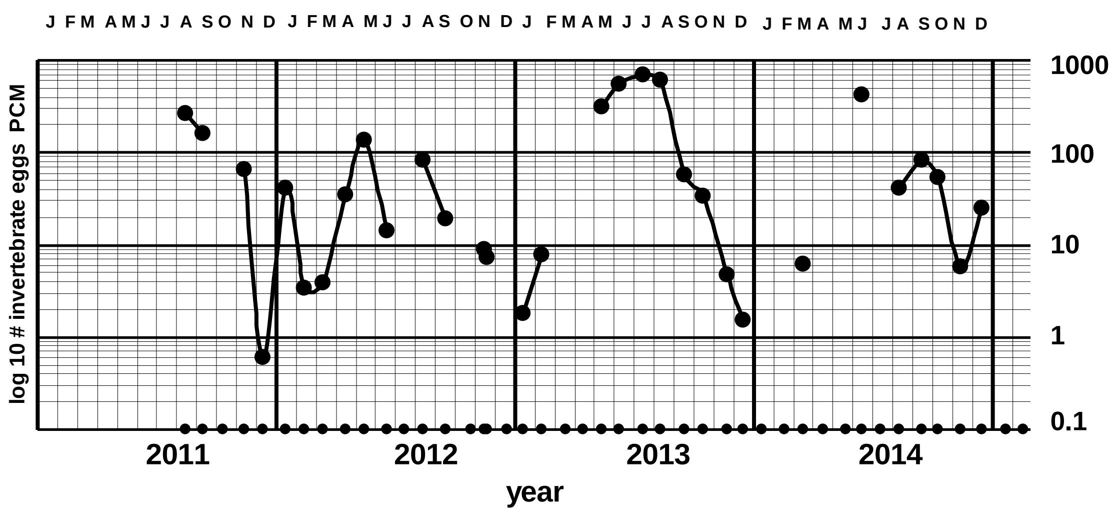


Figure 83. Invertebrate egg density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Density equal to or greater than one hundred per cubic meter was observed in the summer season of 2011, in the spring and summer of 2012, in the spring and summer of 2013, and in the spring and fall of 2014.

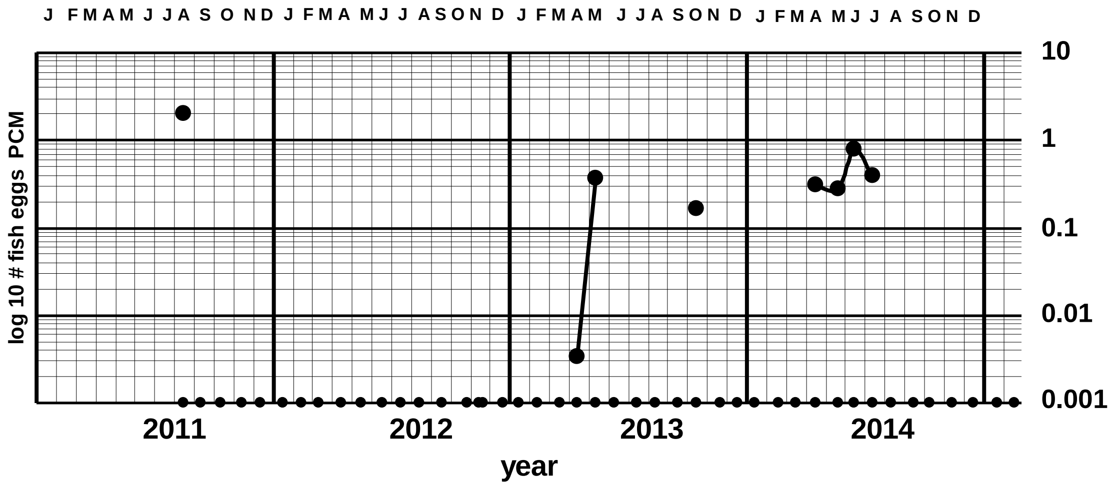


Figure 84. Fish egg density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

In 2012 fish eggs were seen in the summer of 2011, in the spring and fall of 3013, and in the spring and summer of 2014. There were no fish eggs observed in 2012. Fish eggs have become more common in the samples since 2011.

Larvae

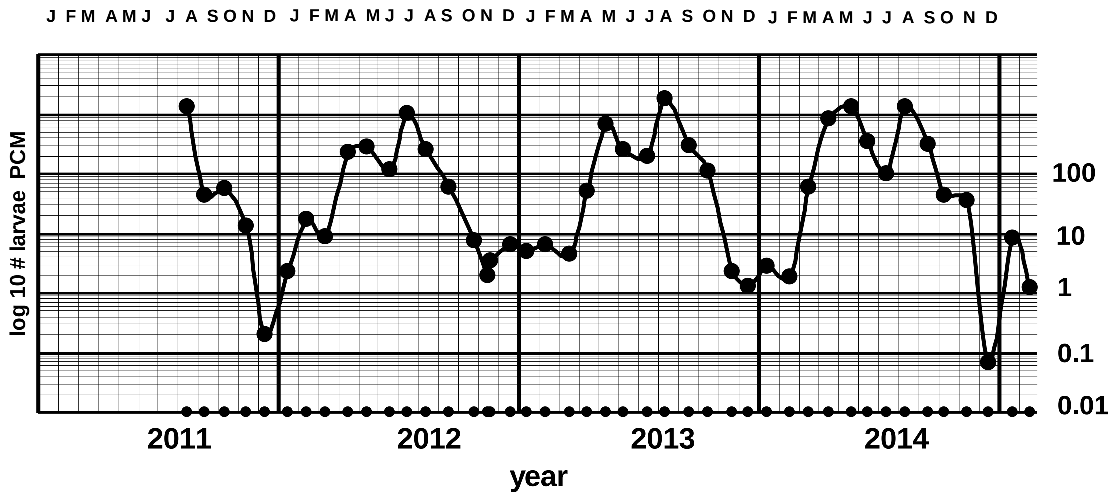


Figure 85. Larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Larvae of Copepoda, parasitic Copepoda, Decapoda, Euphausiacea, Cirripedia, Polychaeta, ascidians and Echinodermata make up this group.

There are density peaks in the spring and in summer seasons. All four summertime maxima are about a thousand larvae per cubic meter between 2011 and 2014. Plankton density was not measured in the spring of 2011 but the other three springtime peaks show an increasing trend.

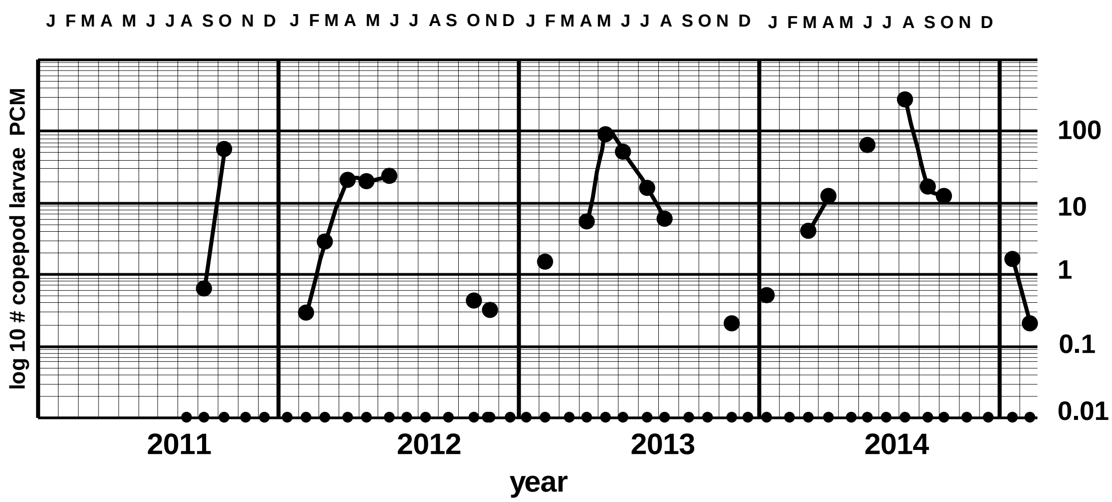


Figure 86. Copepoda larva (nauplius) density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There was an increasing trend in copepod nauplius density over the last four years. There were seven observations in each of the years that were completely sampled. Nauplius larvae were found in all seasons with peaks in density seen from May to August

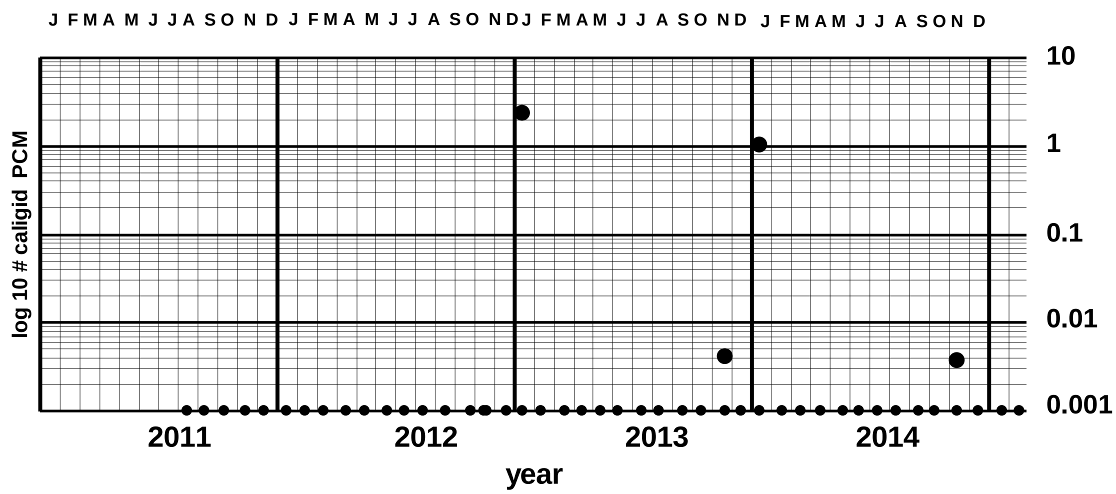


Figure87 . Caligid Copepoda (nauplius to subadult) copepod density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

These caligid copepods all, ***Lepeophtheirus salmonis*** , were seen in January and November in both 2013 and 2014. January density was almost three orders of magnitude greater than in November.

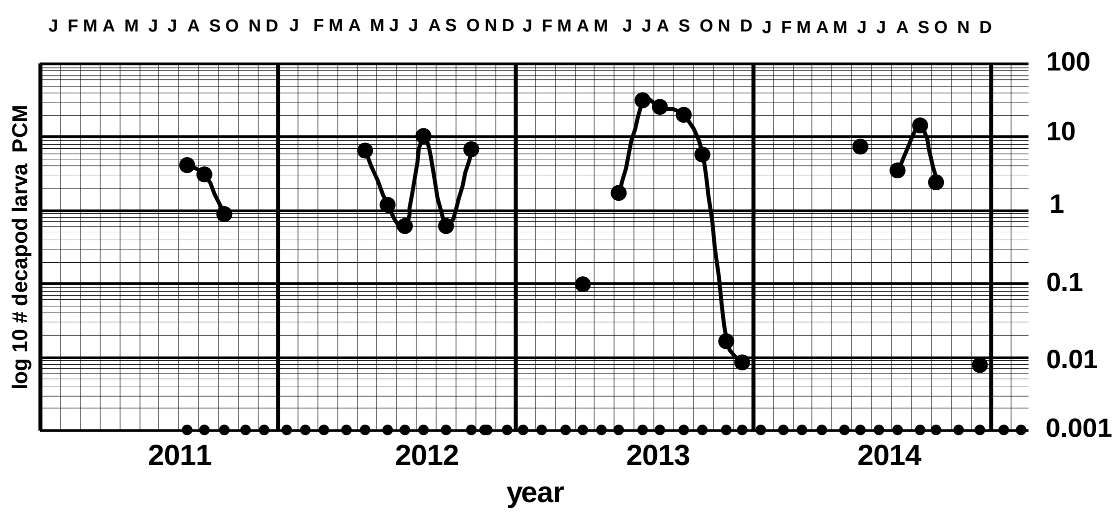


Figure 88. Decapoda larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There were significantly fewer observations of decapod larvae with the fine mesh than with the coarse mesh net and there was slight increase in density peaks between 2011 and 2013. In 2014 peak density occured in September and the peak is slightly lower than that of the previous year.

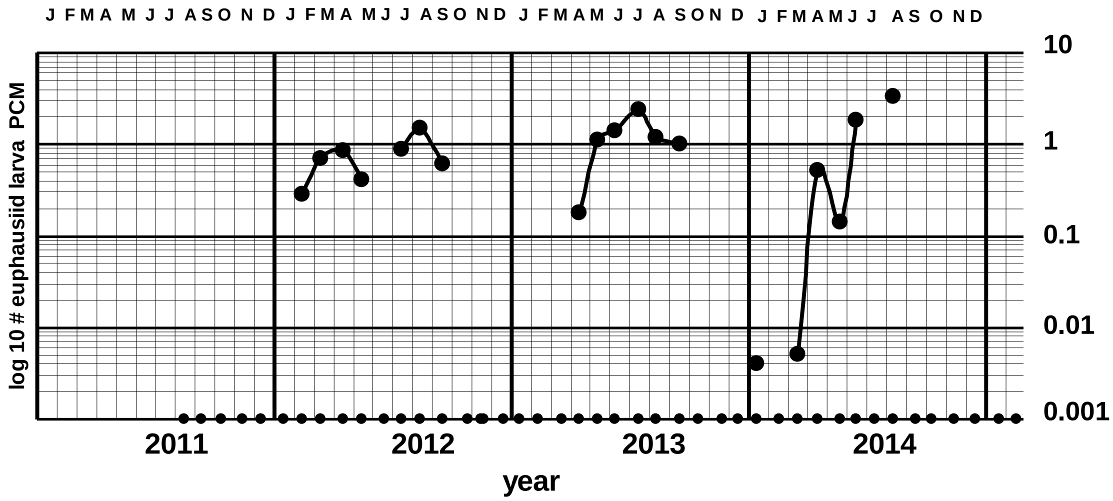


Figure 89. Krill (Euphausiidae) larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There were two density peaks in 2012; one in early spring and one in mid-summer. A slight increase in peak density was apparent between 2012 and 2014.

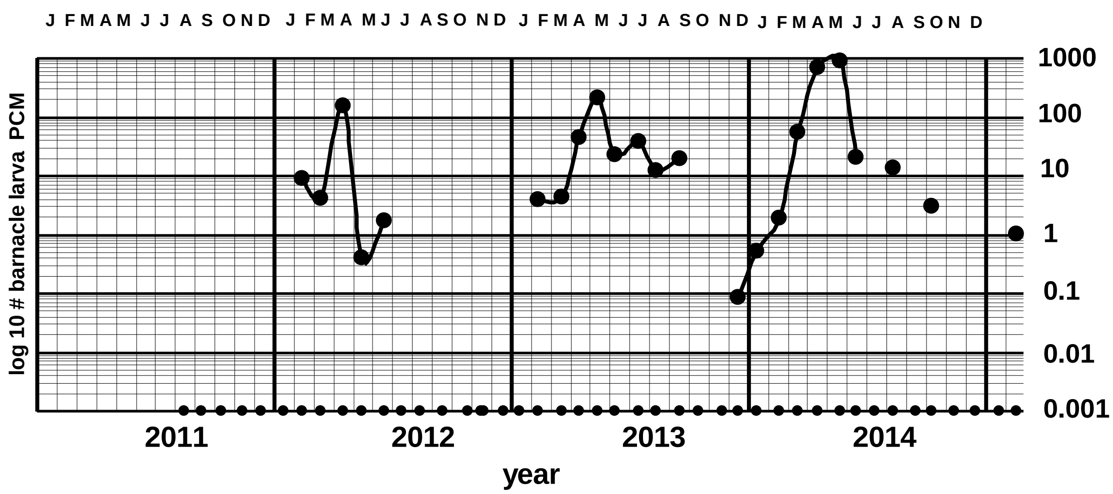


Figure 90. Barnacle (Cirripedia) larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Barnacle larvae density peaks were in April, May and June in 2012, 2013 and 2014 respectively. In 2012 barnacle larvae were present in winter and spring, in 2013 they were around until September and in 2014 until October. Peak density has increased one order of magnitude since 2012

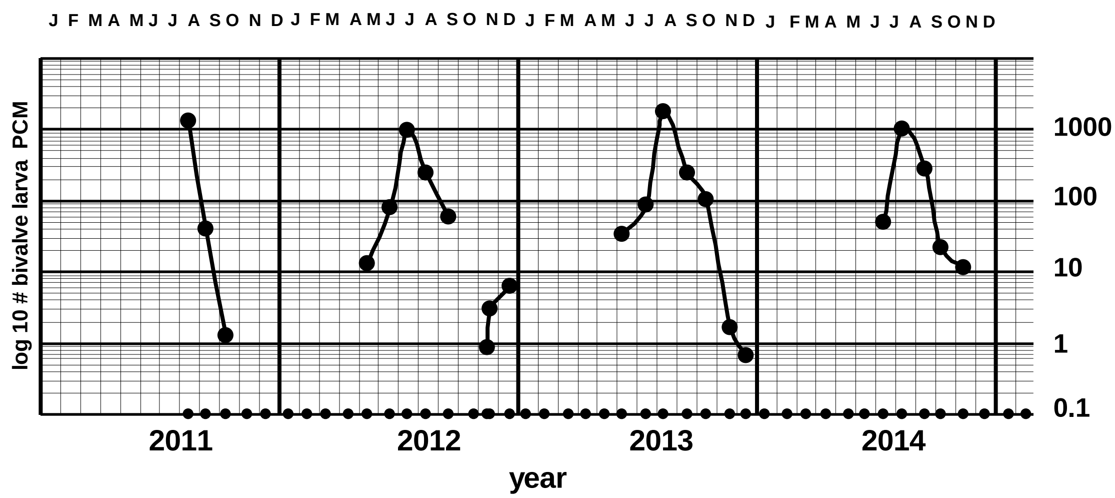


Figure 91. Bivalve (Pelecypoda) larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.
The larvae of bivalves showed a consistent pattern of density peaks in July or August of about one thousand per cubic meter.

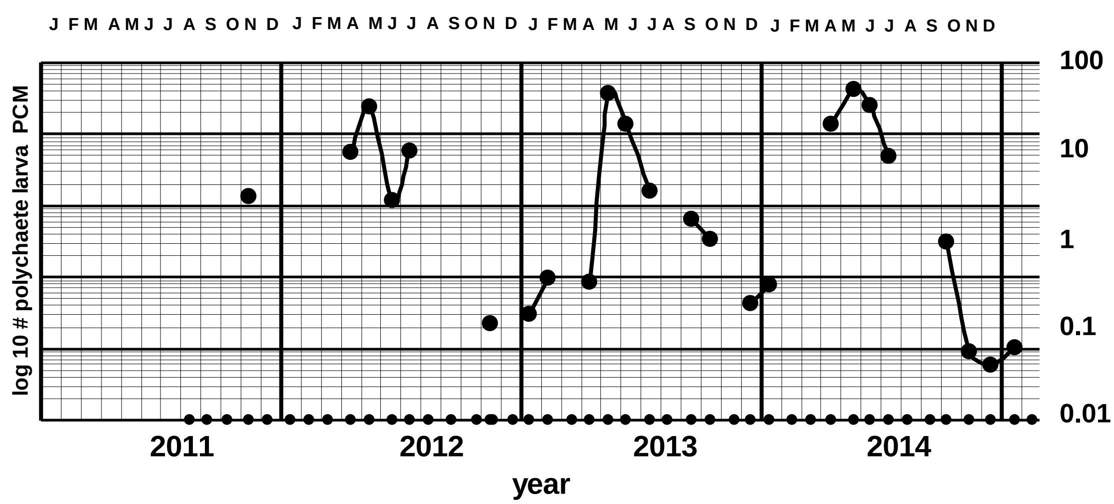


Figure 92. Polychaeta larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Polychaete larvae showed a consistent pattern of peaks of density in May of between one hundred and one thousand per cubic meter.

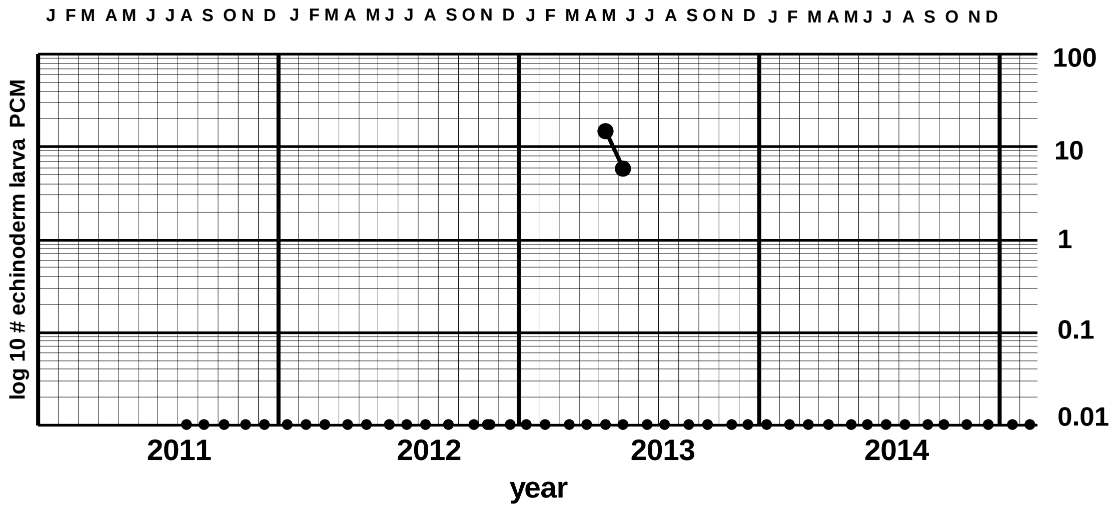


Figure 93. Echinodermata larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There were two observations of echinoderm larvae in May and June of 2013.

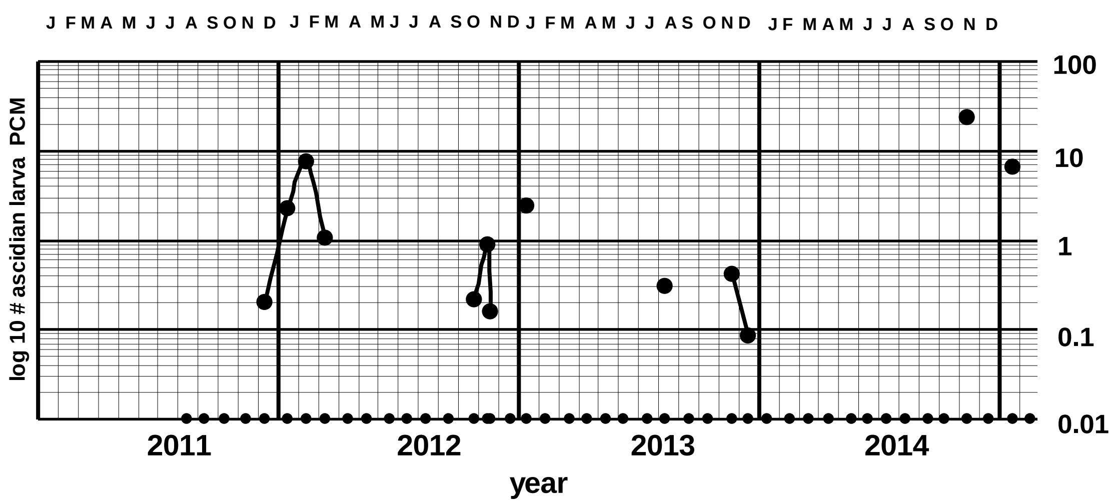


Figure 94. Ascidian larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Ascidian larvae were observed mostly in fall and winter and showed a decreasing trend between 2011 and 2013. There wass record peak density of eleven per cubic meter in November of 2014 and a high density observed in January of 2015.

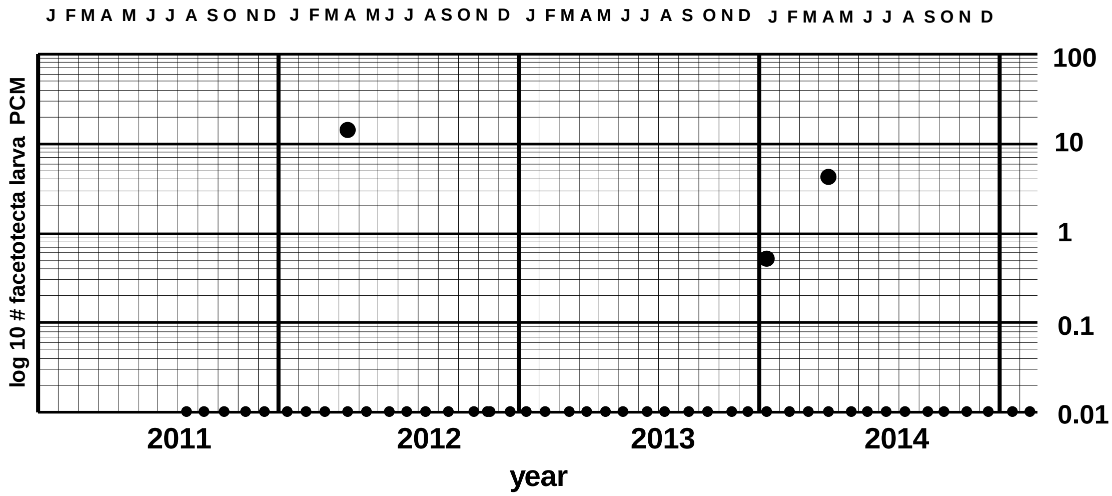


Figure 95. Facetotectan (Cirripedia) larval density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

These Cirripedia are related to barnacles and are believed to parasitize other members of the Class Crustacea. They were observed in April of 2012 and 2014 at a density of less than one and more than ten per cubic meter. There was also an observation in August of 2014.

Type 1 predator

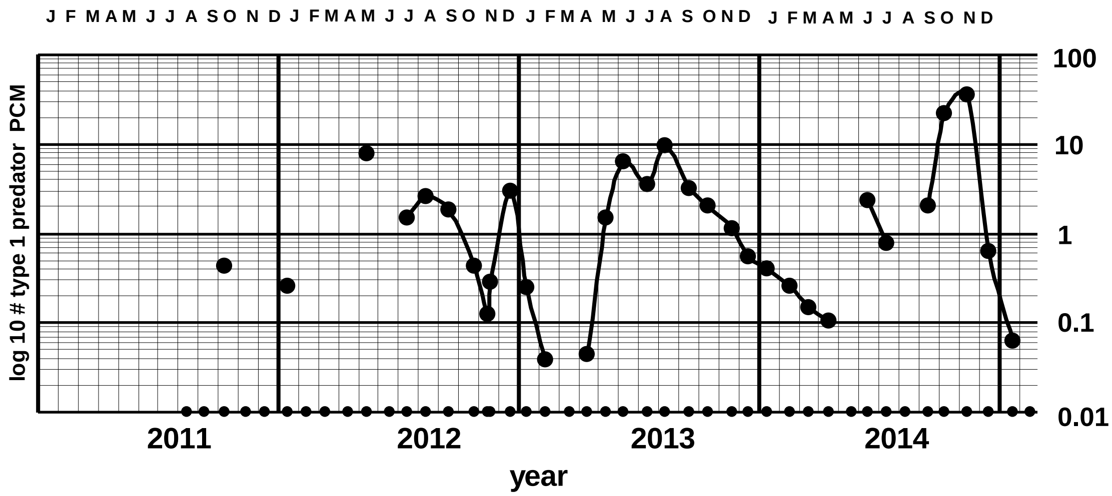


Figure 96. Type 1 predator density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Amphipoda, Chaetognatha, Polychaeta, Isopoda, Ostracoda and larval fish make up this group.

The fall density of type 1 predators has increased 2 orders of magnitude between 2011 and 2014.

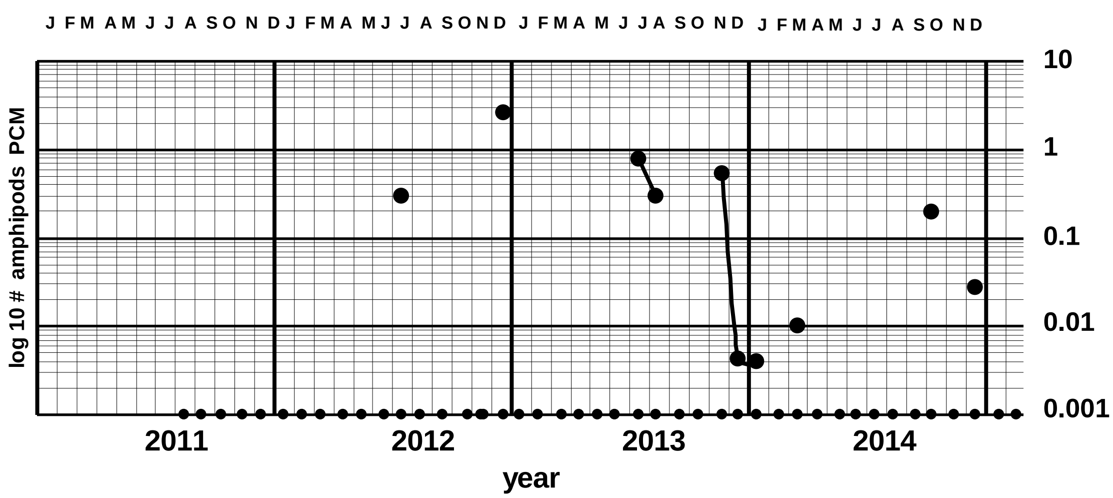


Figure 97. Amphipoda density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Amphipods were observed in July and December of 2012 and four times each in 2013 and 2014. There may have been a slight decrease in density since 2012.

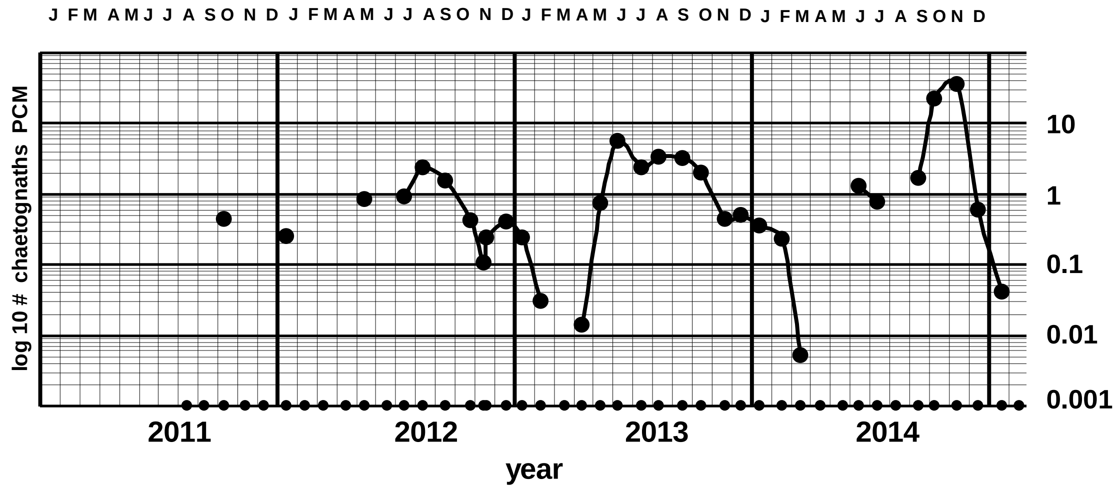


Figure 98. Arrow worm (Chaetognatha) density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

The density of arrow worms in the fall has steadily increased between 2011 and 2014. Peak density was one per cubic meter in August of 2012, six per cubic meter in June and above two per cubic meter until of October of 2013, and thirty per cubic meter in November of 2014.

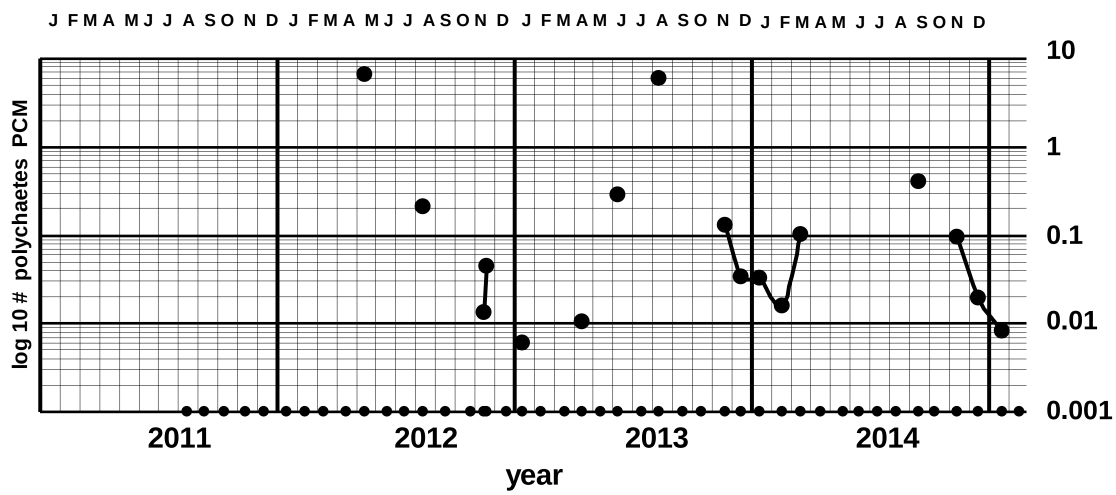


Figure 99. Bristle worm (Polychaeta) density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Between May of 2012 and August of 2013 there was an interesting symmetrical pattern of decline and recovery of density with mostly intermittent observations. The pattern repeated itself in 2013-2014 and 2014-2015.

There were no observed isopods or ostracods in the fine mesh tows.

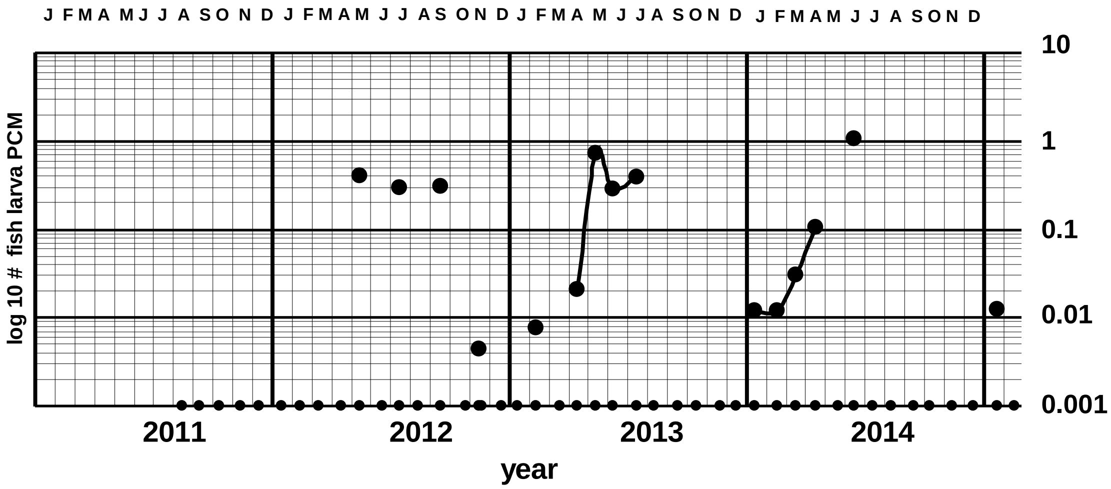


Figure 100. Larval fish density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Larval fish density peaked in May of 2012 and of 2013. In 2014 the highest density was in June.

Type 2 predator

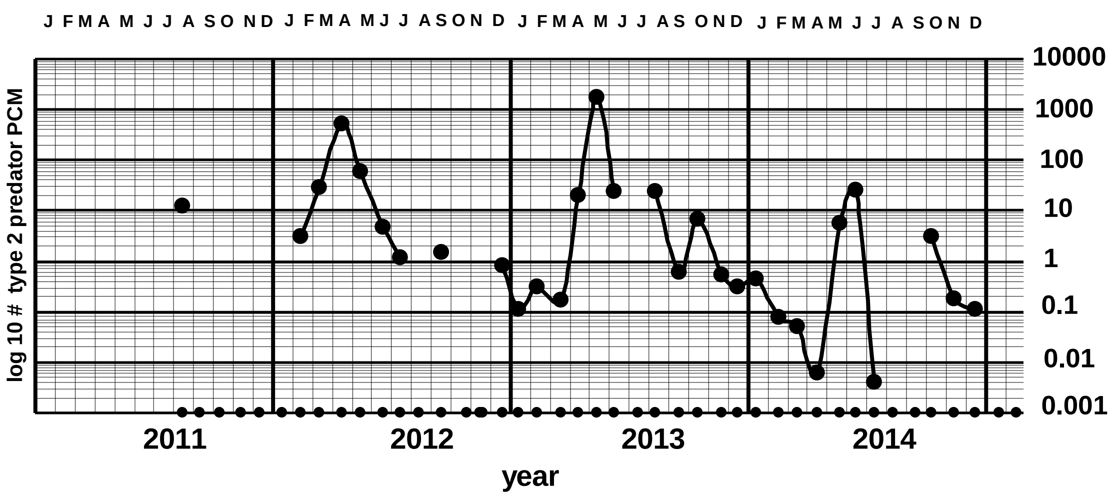


Figure 101. Type 2 predator density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Type 2 predators Cnidaria as well as Ctenophora.

Peak density of these predators was in April, May and June of 2012, 2013 and 2014 respectively. There was a decreasing trend in density since 2012.

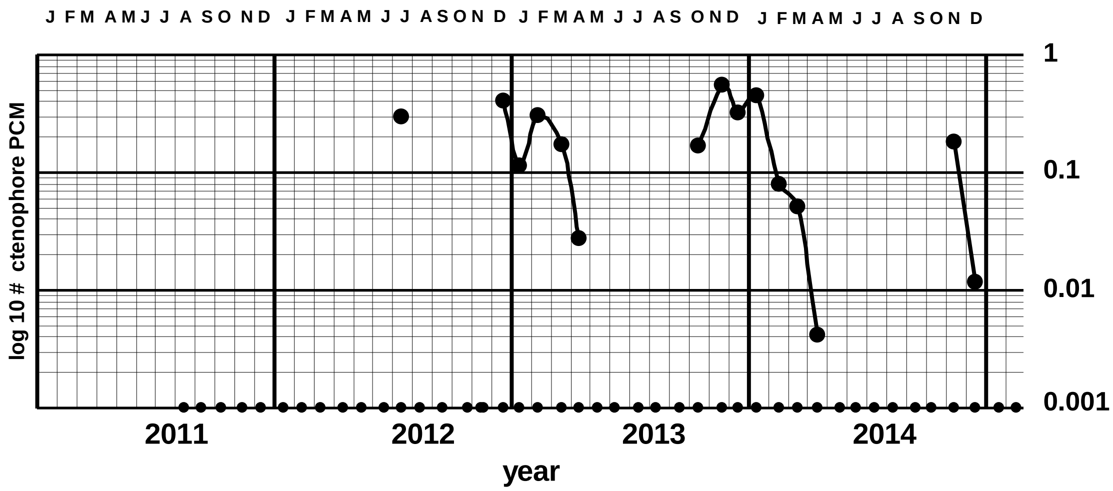


Figure 102. Ctenophora density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Ctenophores were not encountered in plankton samples until June of 2012. They were seen in the fall and winter of 2013 and 2014.

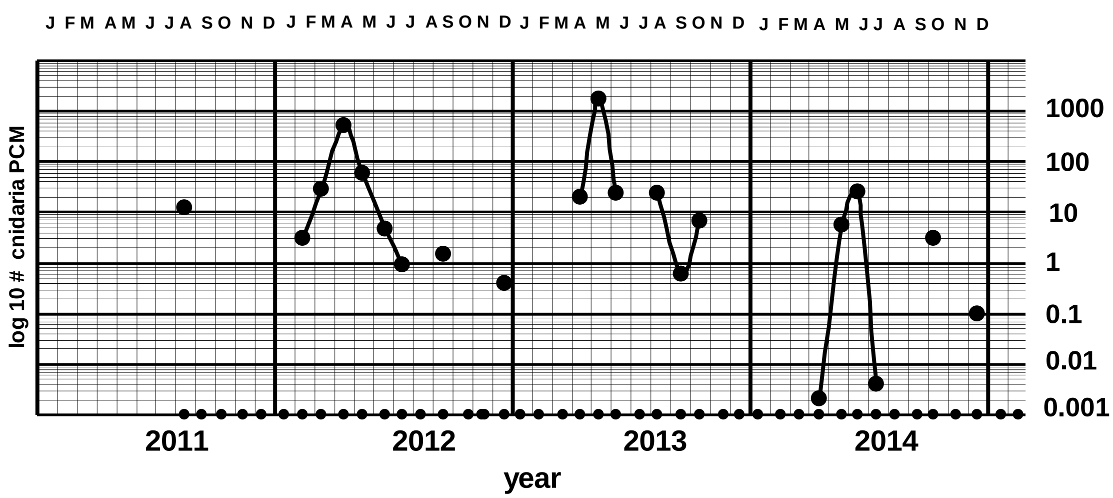


Figure 103. Cnidaria density (number per cubic meter) as estimated from fine mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Peak density of cnidaria wass in April, May and June of 2012, 2013 and 2014 respectively. There wass a decreasing trend in density since 2012.

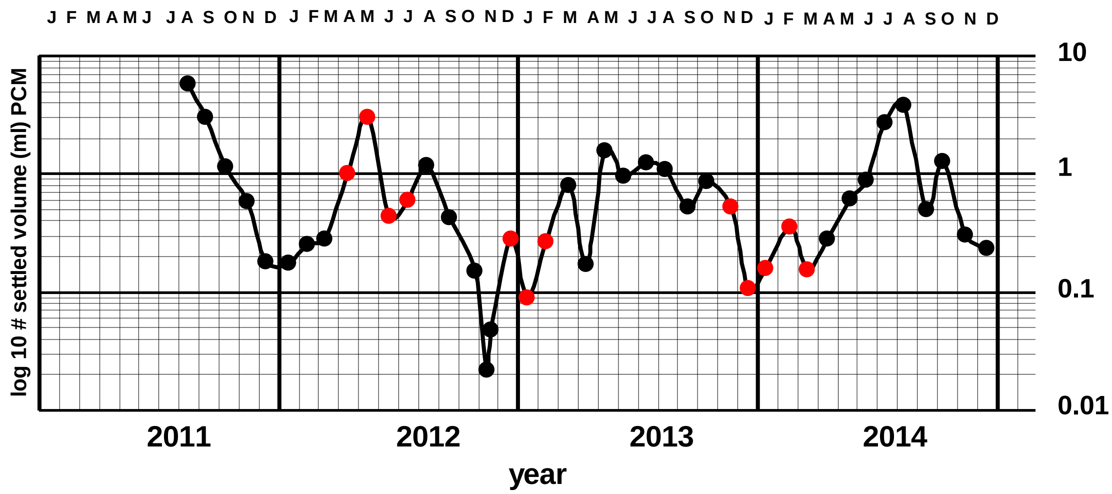


Figure 104. Settled volume (ml per cubic meter) as estimated from fine mesh subsurface plankton tow. Jellies were evident in the sample jars marked in red.

Jellies were not obvious in the jars of samples from the fall of 2011. They were evident in five sample jars from 2012, The largest volume was in August of 2011. In 2012 there was a larger spring and smaller summer peak. In 2013 the pattern was similar but in 2014 there was a large summer peak followed by a smaller fall peak.

Coarse mesh subsurface plankton tow monthly time series: October 2011 – February 2015

In these graphs the time series of density (number per cubic meter) of more than two dozen zooplankton taxa have been put into functional groups, eggs and larvae. Dots on the abscissa mark sampling dates.

The coarse mesh net samples large copepods and post nauplius larval stages of the copepod ***Calanus sp.*** Phytoplankton that fills the fine mesh net is not usually retained. This makes picking larval fish out of a sample a lot easier.

Setal feeders	Calanoid Copepoda Euphausiidae Mysinae Cladocera Cumacea
Mucous feeders	shelled Pteropoda Larvacea
Eggs	invertebrate fish
Larvae	Copepoda parasitic Copepoda Decapoda Euphausiidae Cirripedia parasitic Cirripedia Bivalvia Polychaeta ascidian Echinodermata
Type 1 predator– raptorial	Amphipoda Chaetognatha Polychaeta Isopoda Ostracoda fish larva
Type 2 predator- entangling gelatinous	tentacled Ctenophora Cnidaria

```
                                              2012                    2013                     2014
taxon                             J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
copepod                           ------ ------------------------------------------------------------------
euphausiid                               --- --                                         --
mysid                               --        ------  ---                       --      --          --
cladocera                                   --    --              -----     --              ----   ---
pteropod                          --     --- ---------  --    -------- -------          ----   ---------
larvacea                          ---   ---      -------   --------------                   ---- -------
invertebrate eggs                        ---  ---  ---             ---     --                --
fish eggs                                 ----------       ---------------------    --- --------------
parasitic copepod larva-subadult          ------   ----  ---  ---              ---                  ---
decapod larva                     ------ ------------------------------------------  ---------------------
euphausiid larva                         ---        --                                           -------
barnacle larva                            -----      --        ---  -----                 --------
bivalve larva                     ---     ----------- --- ---       ---       ---                  ---
polychaete larva                   --     ---             --------  -- ---      ------  ------      -------
echinoderm larva
ascidian larva
facetotecta larva
amphipod                           -- --- --- -------- ------ ----- --------  -------   --  --  ----  -----
chaetognath                        ------ ---- ------------------------------------------ ----     --------
polychaete                         ---    --------  ----------   ------ -----------      -----  -------------
isopod                             --           --                                 --           --
ostracod
fish larva                         ----- -------------    ---------------------    ---------------------
ctenophore                                      ------  ----  -----     ---------------------   --   ------
cnidarian                          ------ ------------------- -------------    ---- ----- ----  --  ----
alligator fish                                                                            ---
four-bearded rockling                          ---                        ----                    ----
cunner                                                                 ---
rock gunnel                                                   ---                    ---
herring                                        -------       ---                                    ----
windowpane flounder                            ---                                               -----
snake blenny                        --    ---               --                       ---
sculpin                             --                      --  ----                ----
silver Hake                                      ---
stickleback adult                    ---
radiated shanny                             ----                  --- ---                   -----
winter flounder                           ---                ---  --------                 -----
sandlance                         --                       ----  ---              --------
snailfish                         ---     ------            -------------           ------------
                                  J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
                                              2012                    2013                     2014
```

Figure 105. Presence/absence of zooplankton taxa from coarse mesh subsurface tows for the years 2012-2014. April 2012 was not sampled.

Setal feeders

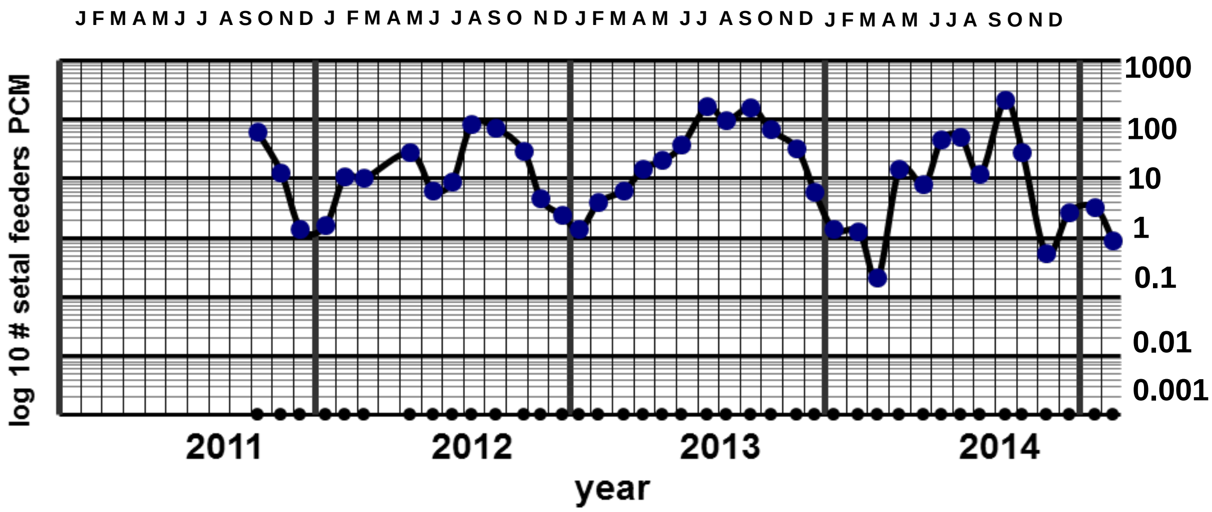


Figure 106. Setal feeding plankton density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Calanoid Copepoda are the main component which also includes Euphausiacea, Mysinae , Cladocera and Cumacea.

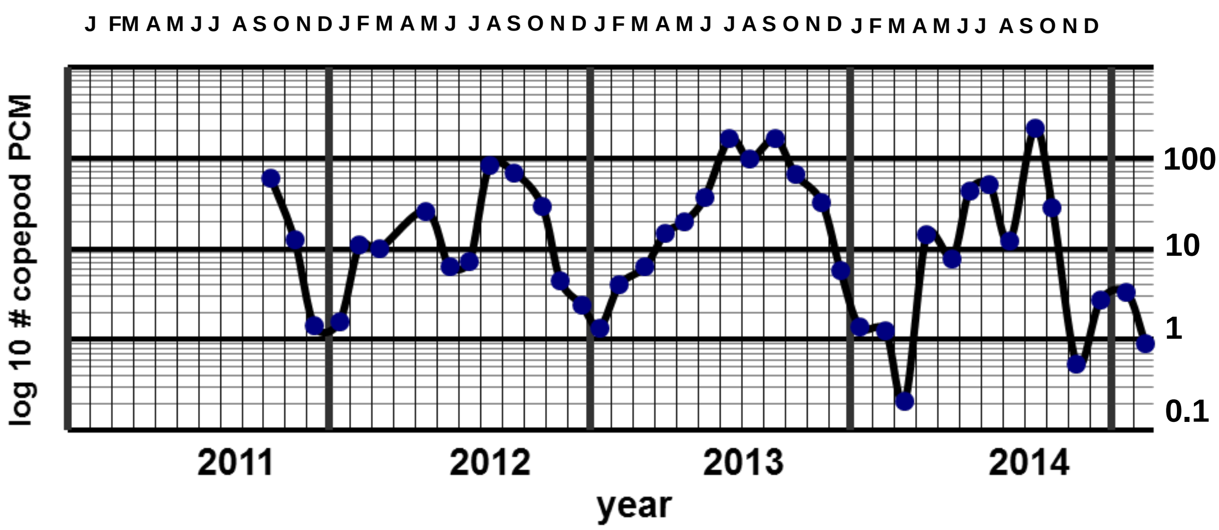


Figure 107. Calanoid Copepoda density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

During the fall of 2011 to 2014 large copepod density decreased from a summer high of about one hundred per cubic meter to about one per cubic meter by winter. From this point, during winter and spring there was a more gradual increase of density from one back to a hundred per cubic meter.

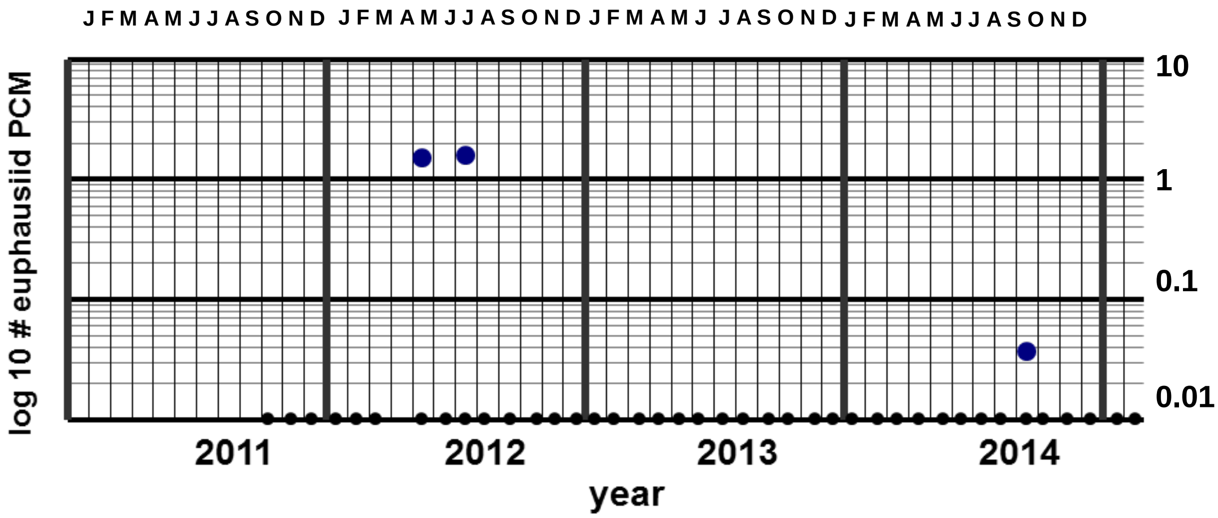


Figure 108. Euphausiidae density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Euphausiids were seen in late spring and summer in 2012 and in late summer in 2014.

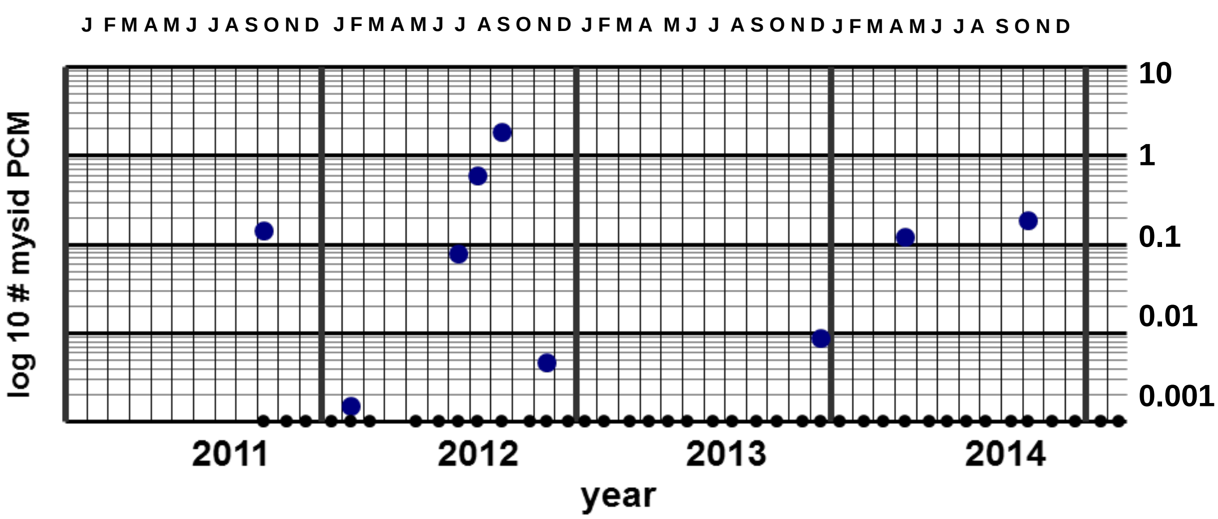


Figure 109. Mysinae density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Mysids were seen sporadically in all four years and were present with increasing concentration throughout the summer of 2012.

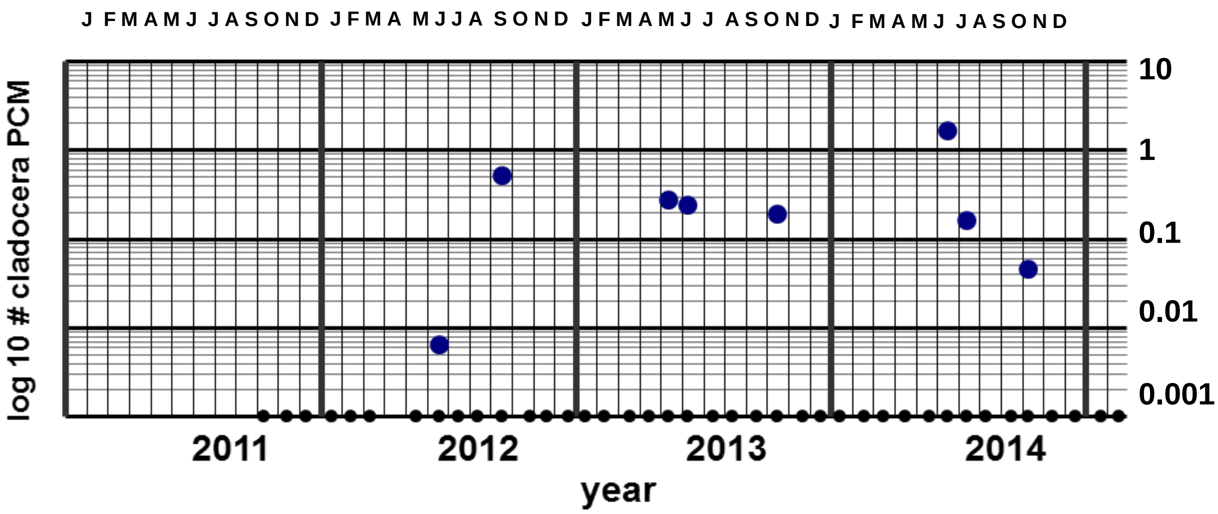


Figure 110. Cladocera density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Cladocerans were found between late spring and early fall from 2012 to 2014. They were first seen in June of 2012 and 2014 and in May of 2013. They were last seen in September of 2012 and in October of 2013 and 2014.

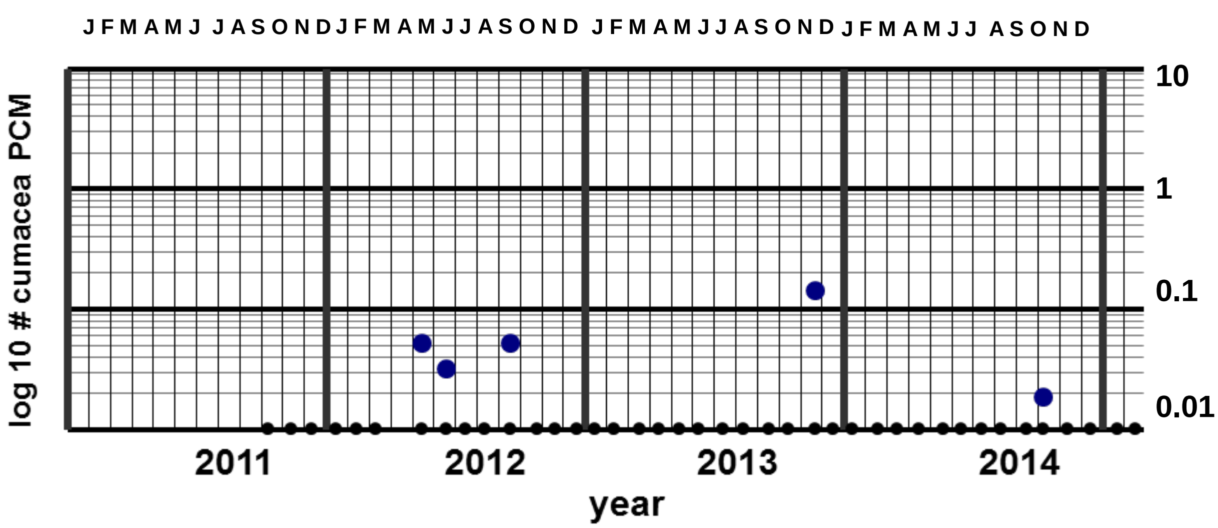


Figure 111. Cumacea density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Mucous feeders

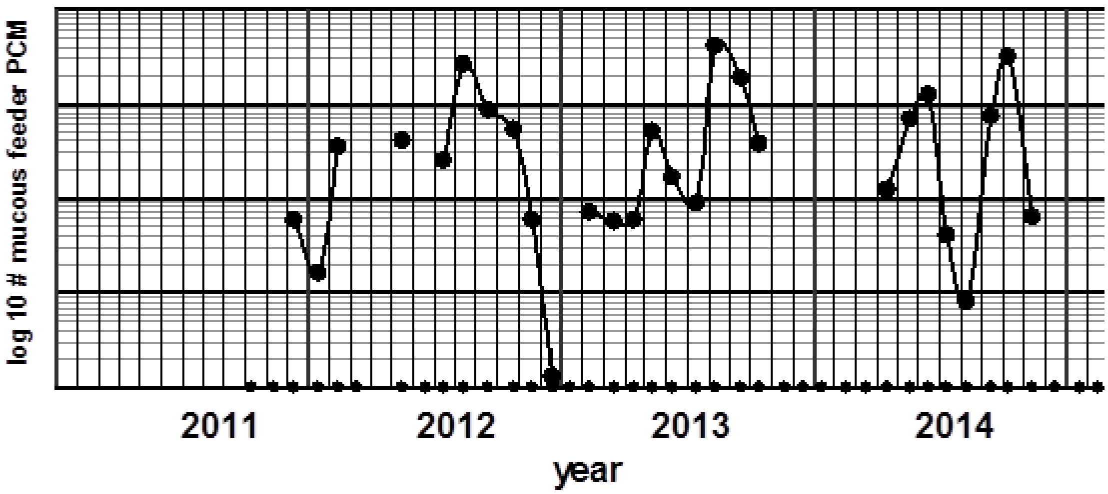


Figure 112. Mucous feeding plankton density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Pteropoda and larvacea make up this group.

Zooplankton taxa that use mucous to feed showed an increasing trend from winter or spring until August.

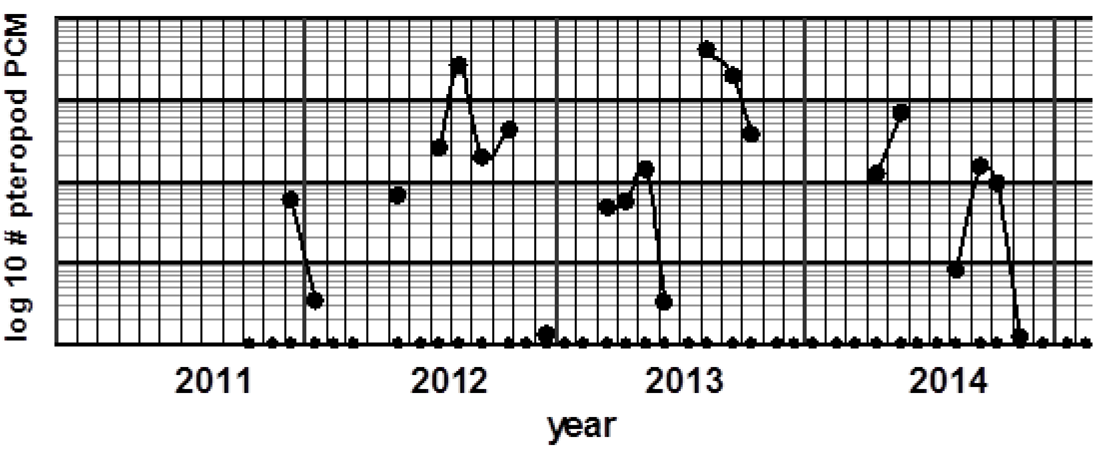


Figure 113. Pteropoda density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Maxima of between one and ten pteropods per cubic meter were found in August of 2012 and 2013. In 2014 density did not exceed one per cubic meter.

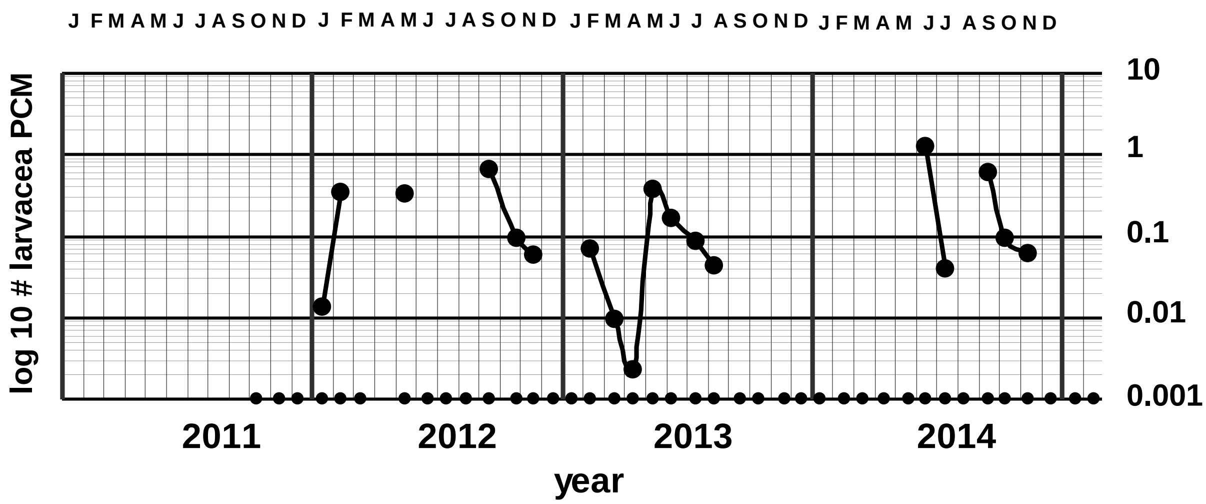


Figure 114. Larvacea density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

The number of larvacea peaked in the summer in 2012 and in the spring in 2013 and 2014. There were fewer observations of larvacea in 2014 than in the two previous years.

Eggs

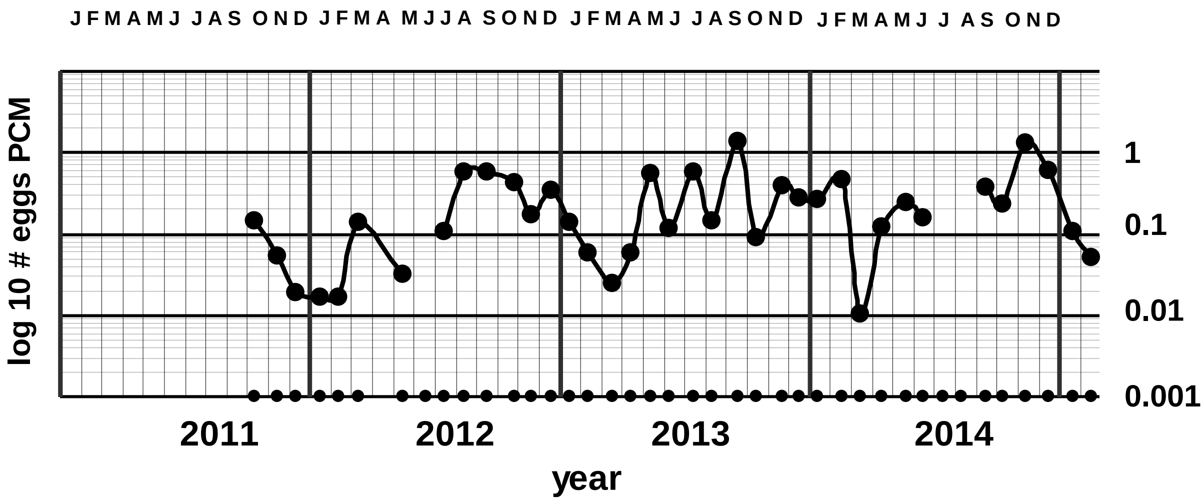


Figure 115. Egg density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. This includes the eggs of fish and of invertebrates.

Between the fall of 2011 and the fall of 2014 egg density has increased gradually. The highest annual density occured in late summer or fall.

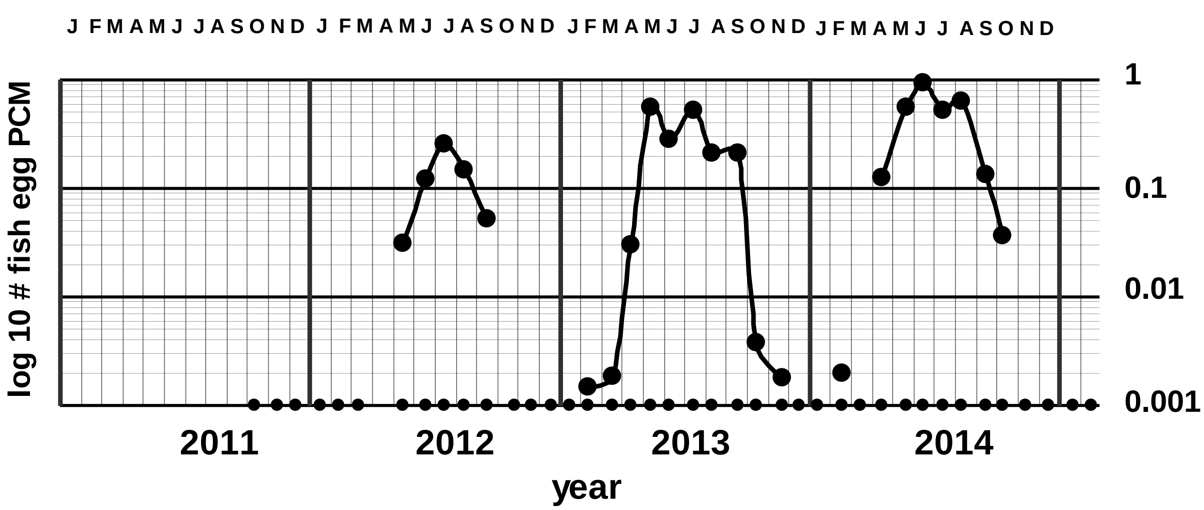


Figure 116. Fish egg density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

In 2012 fish eggs were more common in June, July and August. In 2013 they were more common from May to September and in 2014 from April to September. There was a gradually increasing trend of fish eggs being more common over a longer period of the spring and summer.

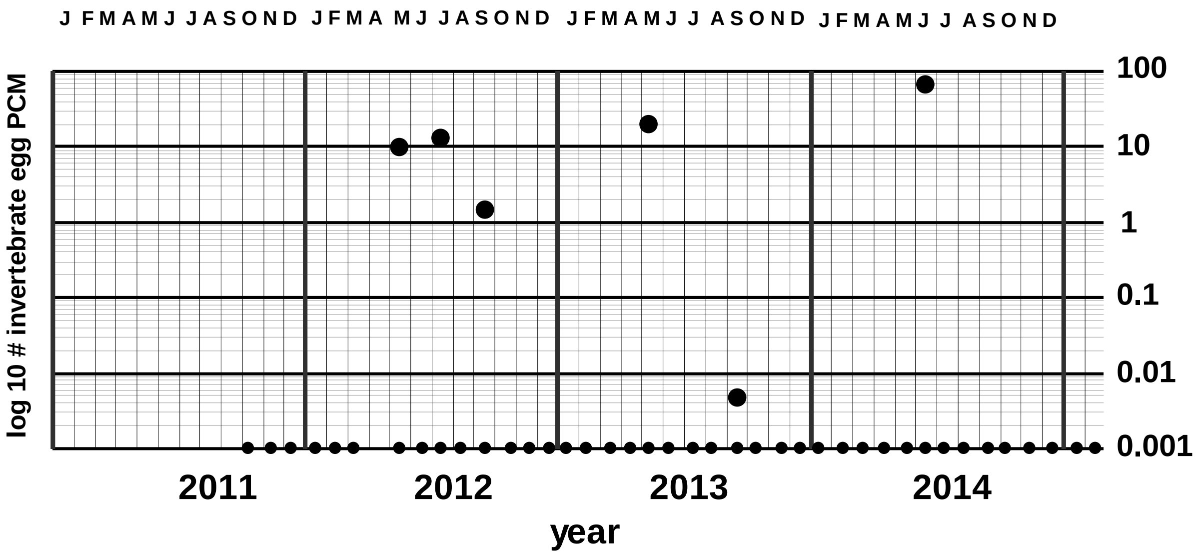


Figure 117. Invertebrate egg density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Larvae

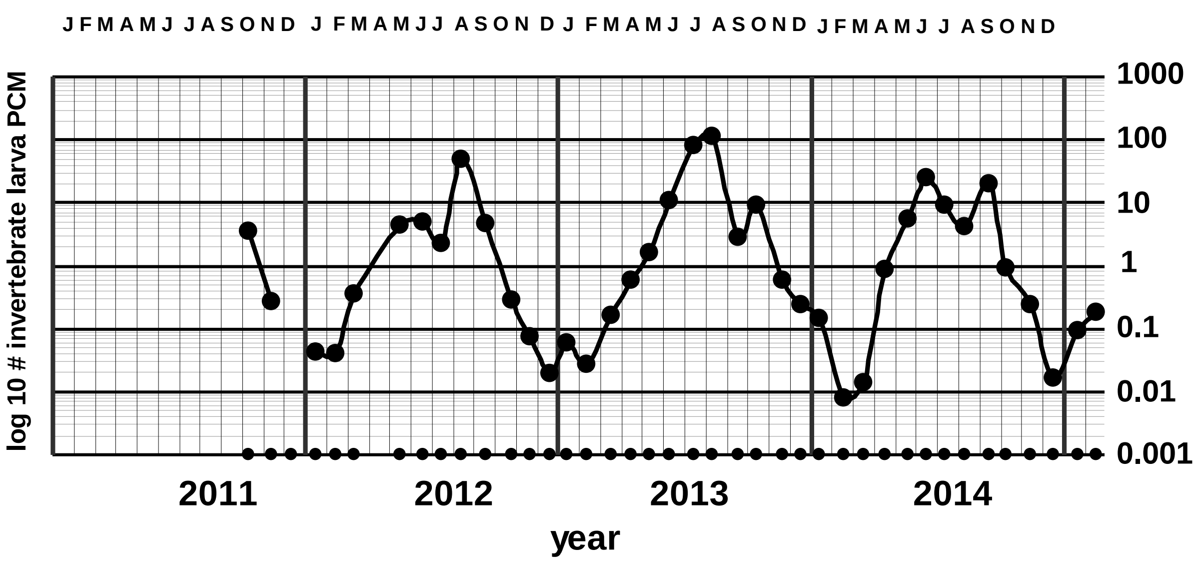


Figure 118. Larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Larvae of Copepoda, parasitic Copepoda,

Decapoda, Euphausiacea, Cirripedia and Polychaeta make up this group.

The annual density increase and decrease was similar in shape to the annual temperature increase and decrease. There was a maximum in summer of between ten and one hundred larvae per cubic meter between 2012 and 2014.

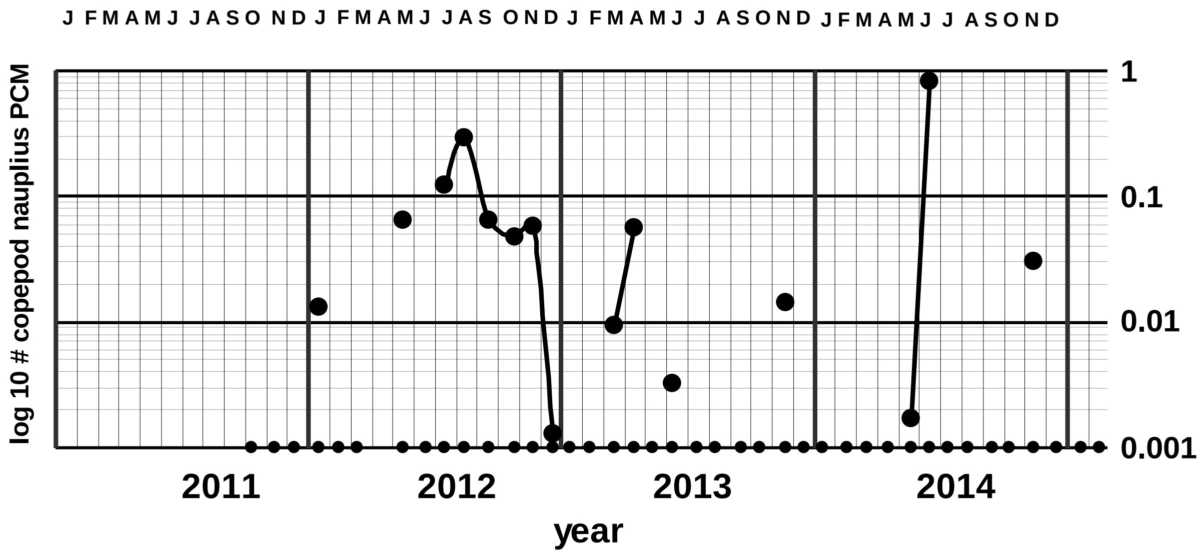


Figure 119. Copepoda larva (nauplius) density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Only large copepod nauplius larvae were sampled by the coarse mesh net and they have become less common in the past three years, occurring three times in 2014, four times in 2013 and eight times in 2012

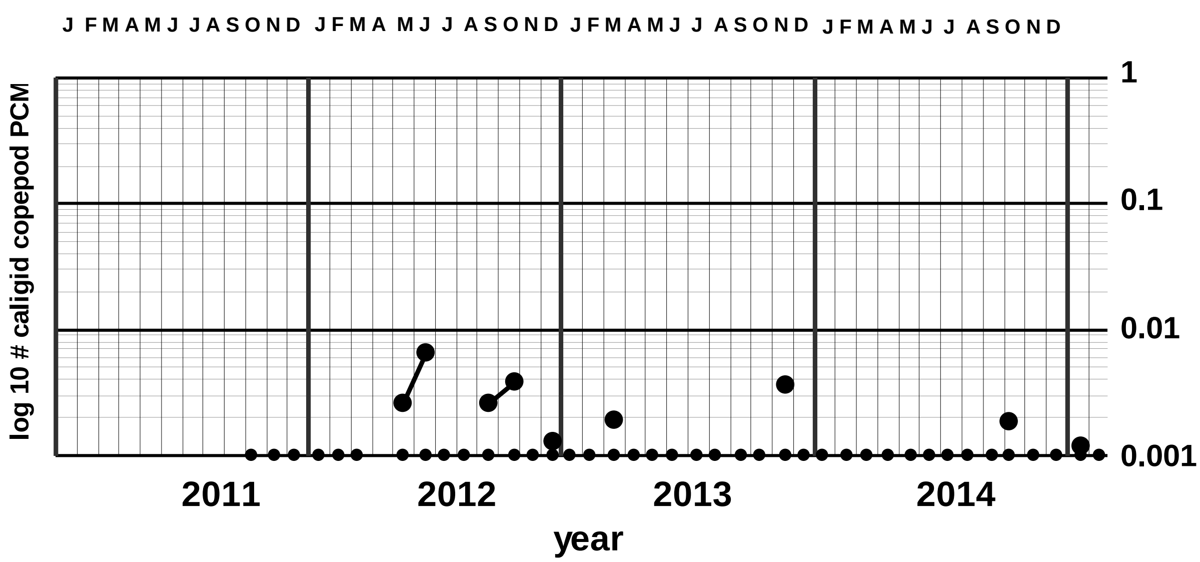


Figure 120. Caligid Copepoda (nauplius to subadult) copepod density (number per cubic meter) as

estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

These caligid copepods all, ***Lepeophtheirus salmonis*** , were seen five times in samples from 2012, twice in 2013 and once each in 2014 and 2015.

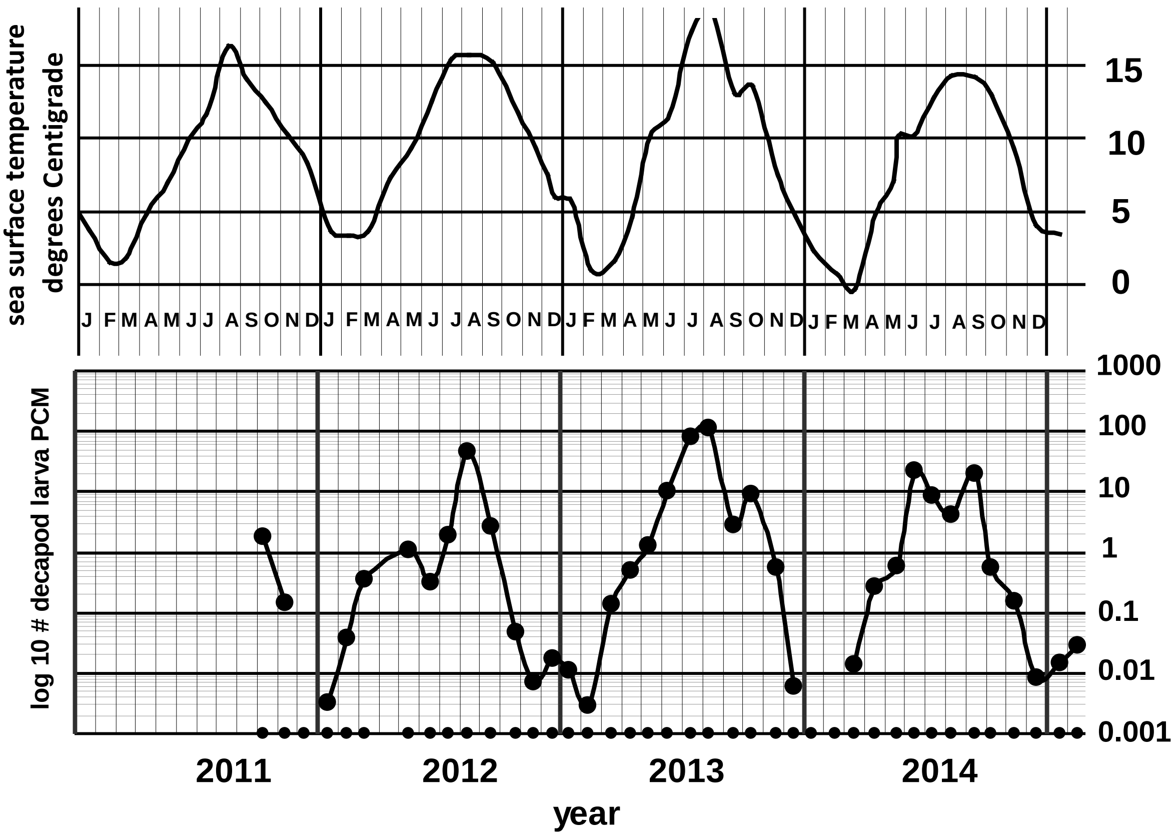


Figure 121. Decapoda larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Corresponding sea surface temperature is plotted above.

The annual density increase and decrease was similar in shape to the annual temperature increase and decrease. Summer maxima of between ten and one hundred larvae per cubic meter occurred between 2012 and 2014.

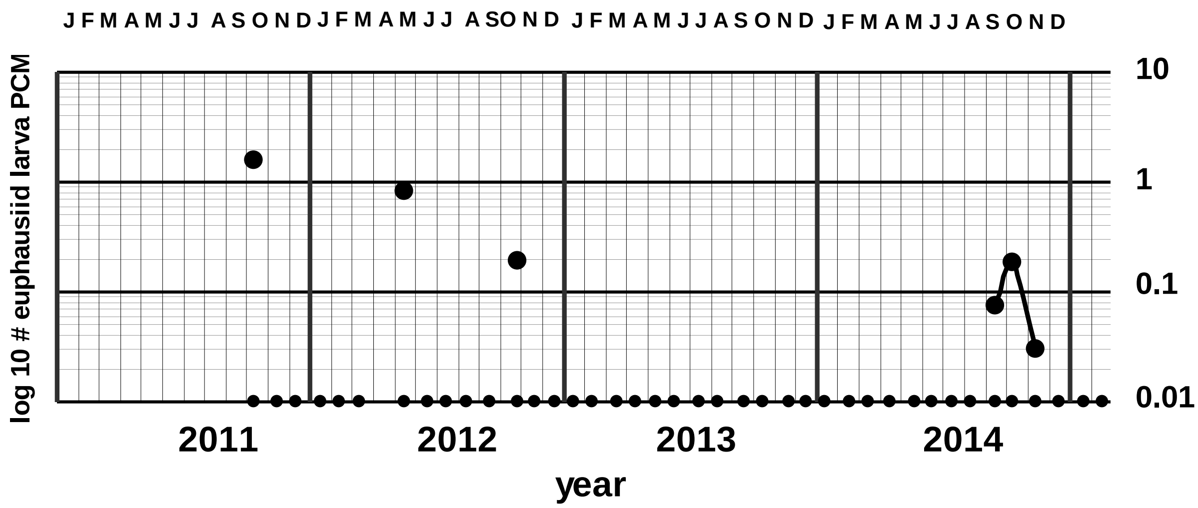


Figure 122. Krill (Euphausiidae) larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Euphausiid larvae were not seen in 2013 but were in October samples of the other three years. In 2014 they were observed for three months in a row in late summer and fall.

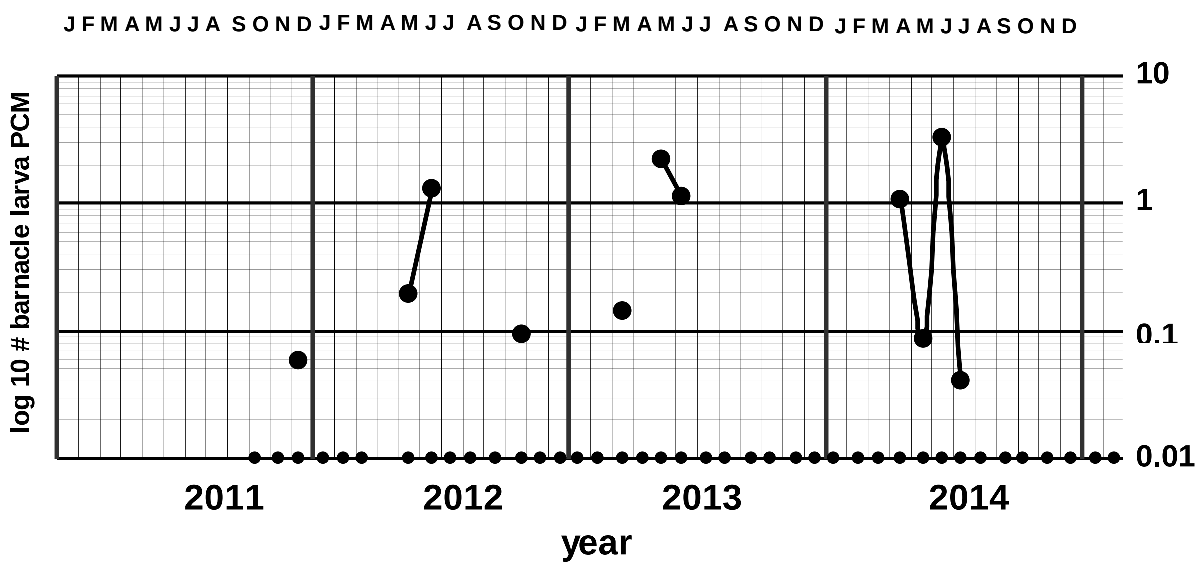


Figure 123. Barnacle (Cirripedia) larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Barnacle larvae were seen in May and June of all years sampled during those months. In 2014 they were first seen in April and again on every sampling visit until July.

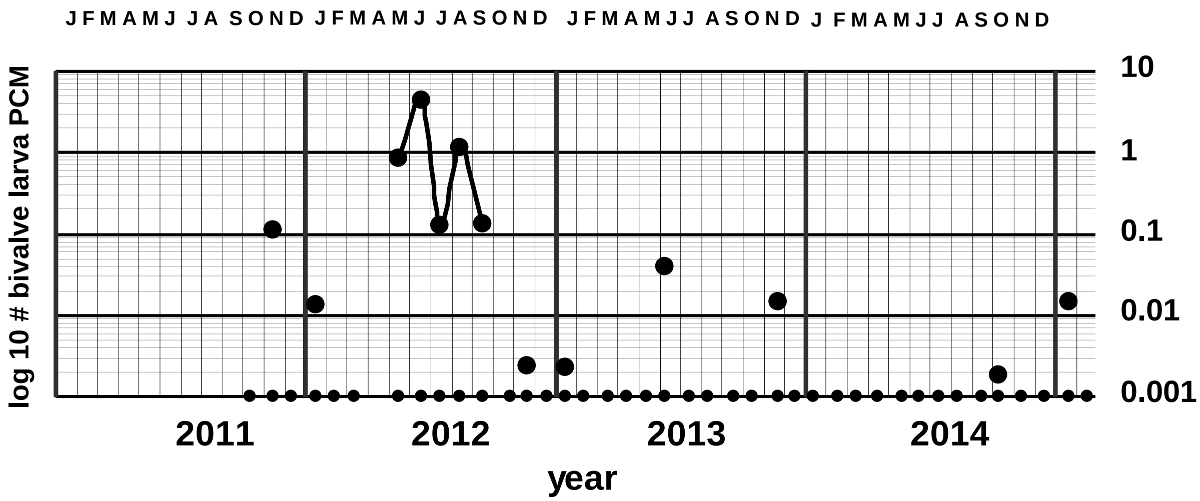


Figure 124. Bivalve (Pelecypoda) larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Bivalve larvae were most common and most concentrated in 2012, occurring in seven samplings. They were only observed three times in 2013 and once in all other years sampled

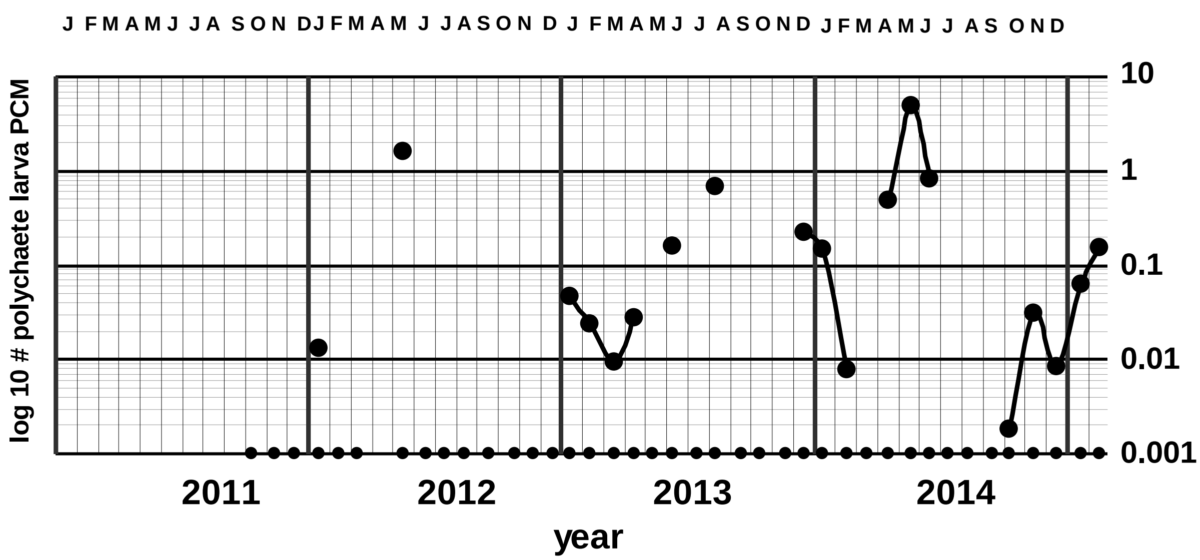


Figure 125. Polychaeta larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Polychaete larvae were observed on two occasions during the winter and spring seasons of 2012. In 2013 they were observed on 7 occasions during all four seasons and in 2014 on eight occasions but not during the summer. Peak density of between one and ten per cubic meter occurred in May of 2012, August of

2013 and May of 2014.

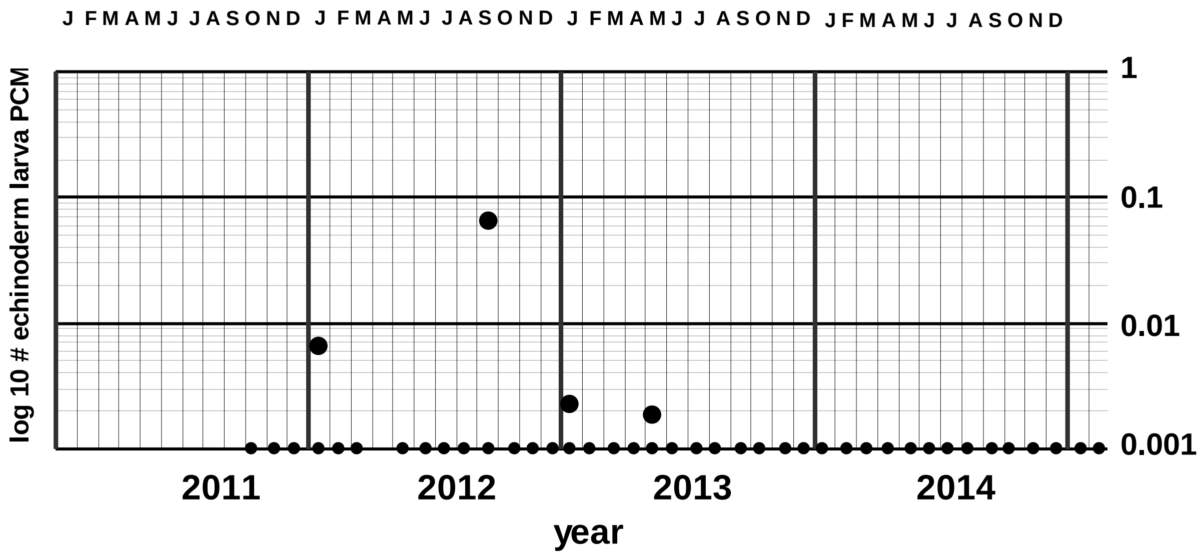


Figure 126. Echinodermata larval density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

These larva were seen twice in 2012 and in 2013; January of both years, September of 2012 and May of 2013. There were no observations of ascidian larvae in coarse mesh subsurface plankton tows.

Type 1 predator

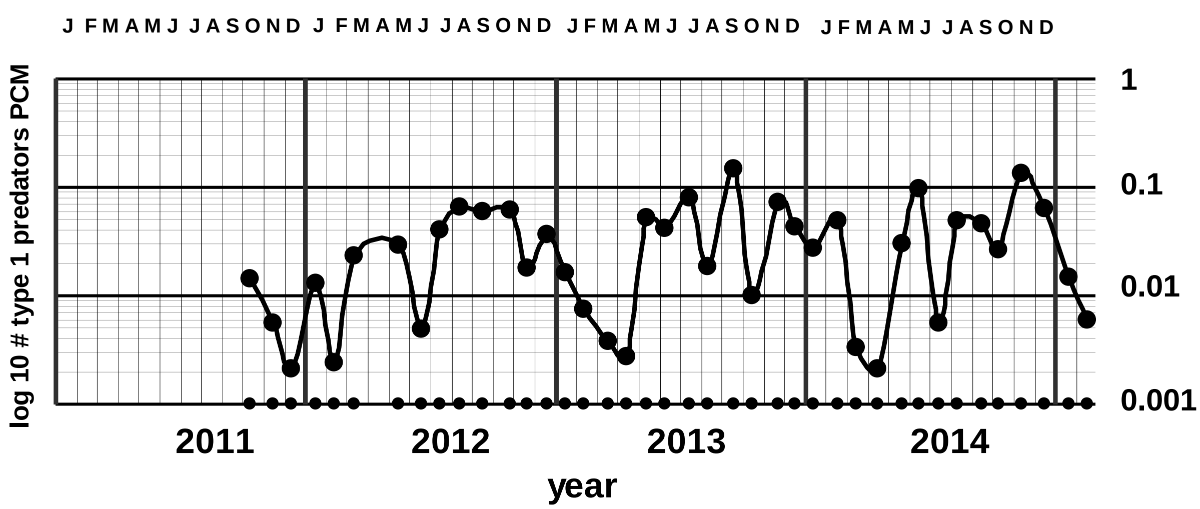


Figure 127. Type 1 predator density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot. Chaetognatha make up the bulk of this group which also includes Amphipoda, Polychaeta, Isopoda, Ostracoda and larval fish.

The fall density of type 1 predators has increased gradually between 2011 and 2014 and the plot is similar in shape to that for eggs.

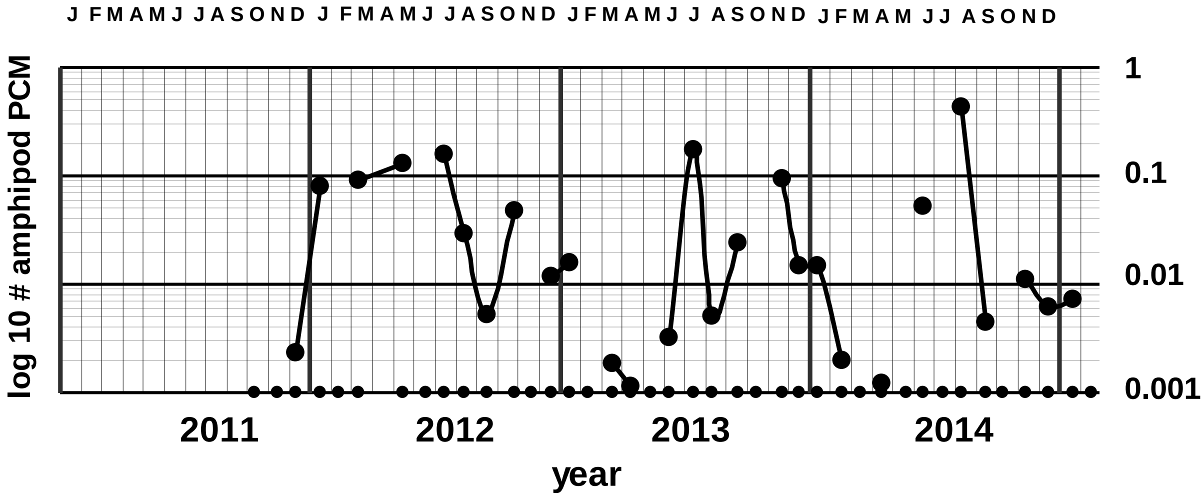


Figure 128. Amphipoda density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Amphipods were not numerous but were found eight or nine times in each of the years between 2012 and 2014 with a peak in July of 2012 and 2013 and in August of 2014.

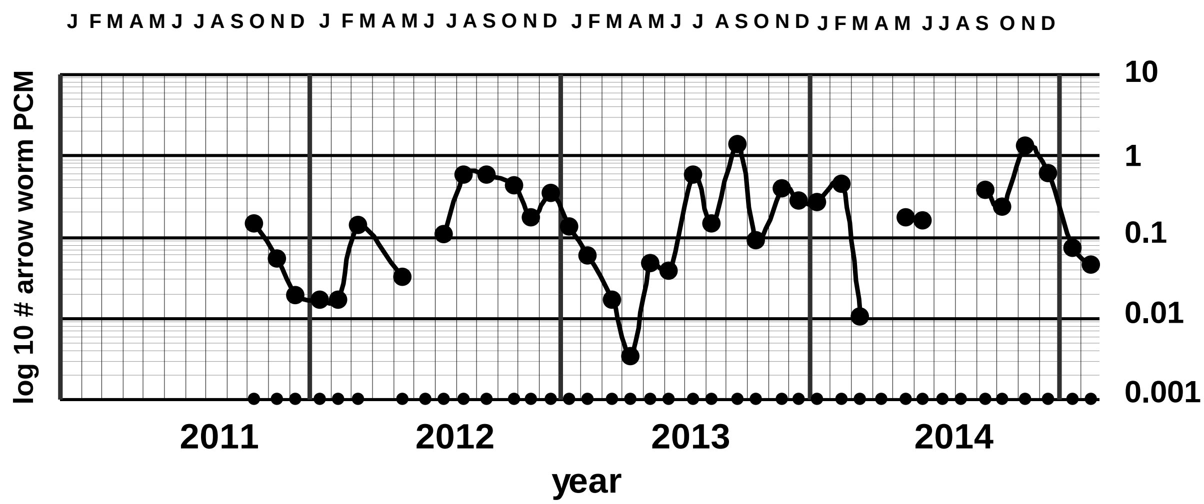


Figure 129. Arrow worm (Chaetognatha) density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

The density of the arrow worm, mainly ***Parasagitta elegans*** with a few ***Eukronia hamata*** in the fall has gradually increased between 2011 and 2014. Maximum density of about one per cubic meter occurred in August and September of 2012, in September of 2013 and in November of 2014. The only year in which chaetognaths occurred on every sampling occasion was in 2013.

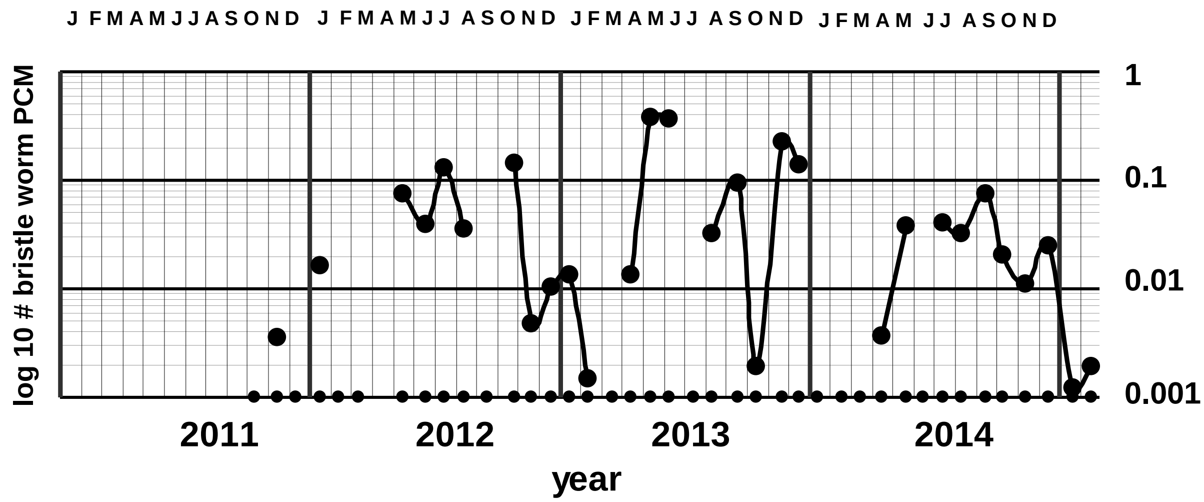


Figure 130. Bristle worm (Polychaeta) density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

There was a build-up of polychaete density between the fall of 2011 and the spring of 2013. There was a steady decline from that point until the winter of 2015

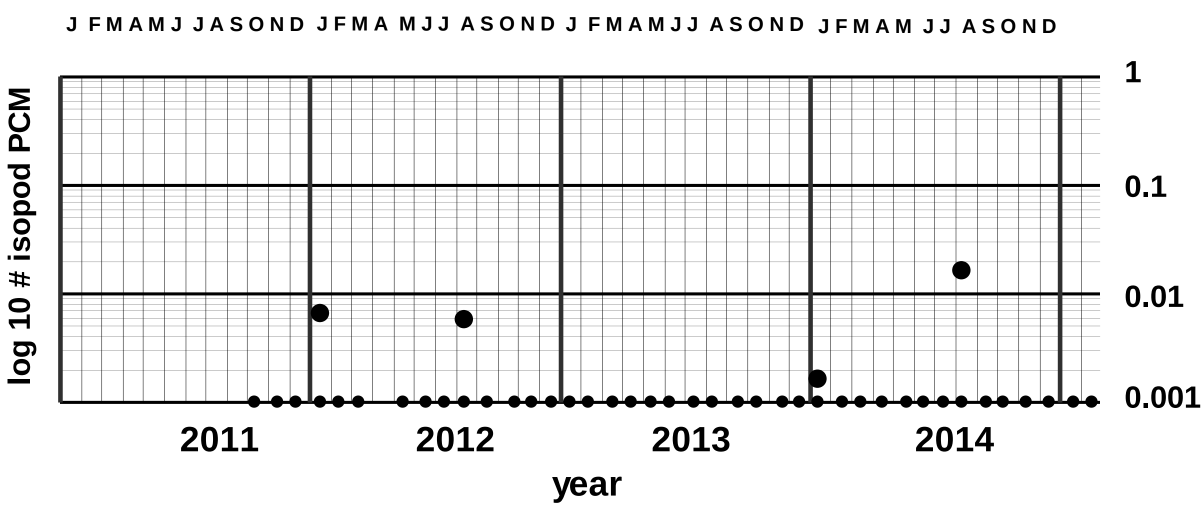


Figure 131. Isopoda density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Isopods were observed in January and August of 2012 and 2014. They were absent from the samples from 2011 and from 2013.

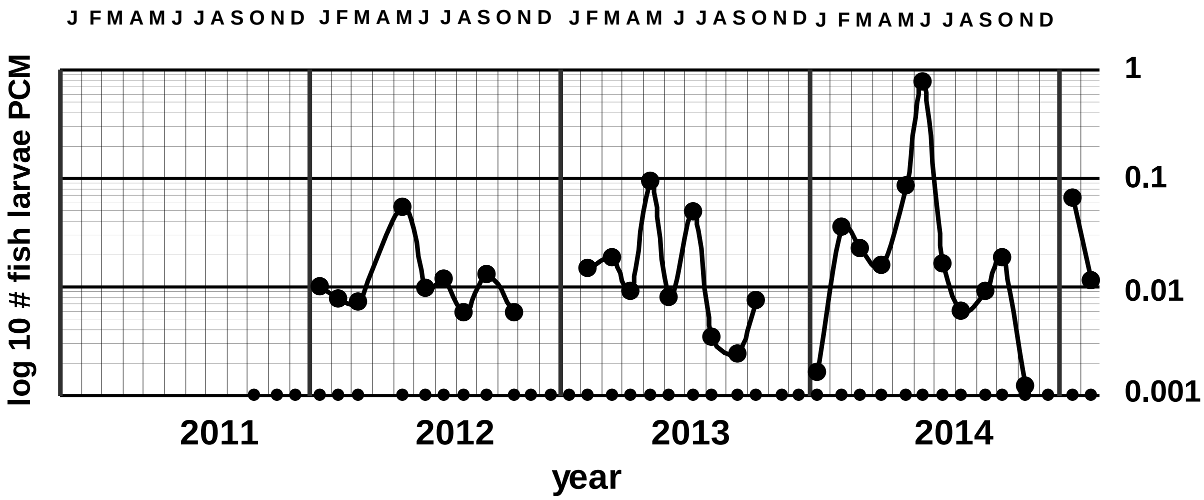


Figure 132. Larval fish density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Larval fish density peaked in May of 2012 and 2013. Larvae were numerous in May and even more so in June of 2014. There seems to be a gradual increase over the past three years.

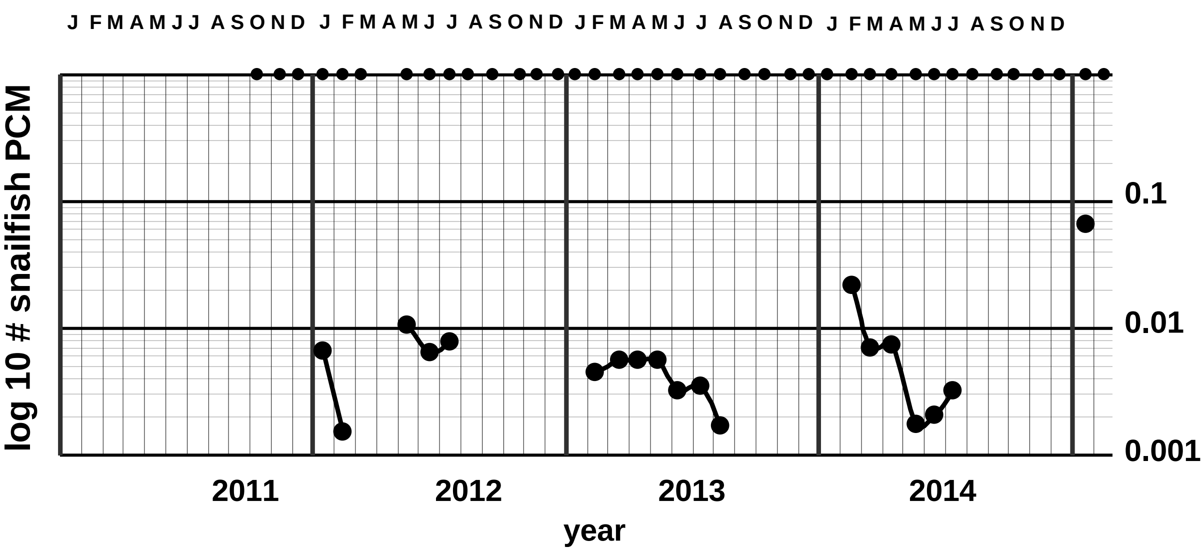


Figure 133. Seasnail=snailfish; ***Liparis sp.*** larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Liparis larvae were found from winter through to early summer. There were fifty-five caught in Jan of 2015. They were seen as early as April in Passamaquoody Bay in the past (Bigelow and Schroeder, 1953).


Figure 134. A seasnail (***Liparis sp***.) larva caught during the monitoring program.

***Liparis sp*.,** a bottom dwelling marine fish that has also been found in a tide pool near St. Andrews in Passamaquoddy Bay (Bigelow and Schroeder, 1953). Diet consists mainly of small crustaceans, small shellfish and worms. It is thought that this species works its way inshore in winter in order to spawn. Spawning is thought to occur from late winter to early June (Scott and Scott, 1988). Eggs are found in clusters, stuck together and to debris or hydroids. Incubation period is about a month and larvae are three and three-tenths to four and one-half mm long (Bigelow and Schroeder, 1953).

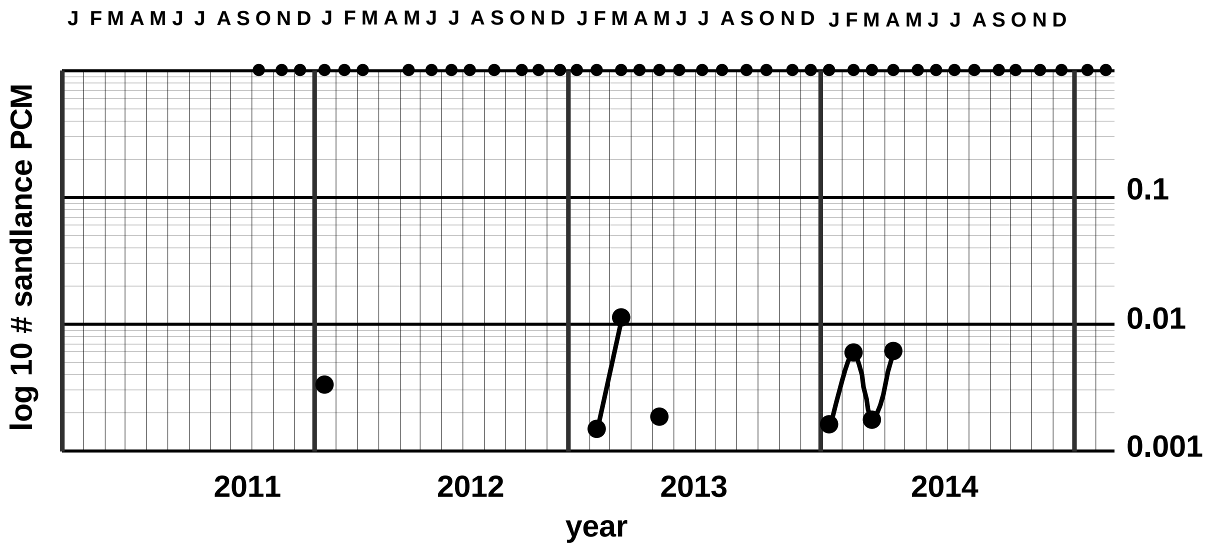


Figure 135. Sandlance; ***Ammodytes sp***. larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Ammodytes larvae were observed in winter from 2012-2014 and in spring of 2013 and 2014.

Figure 136. ***Ammodytes sp***. (sandlance) larva caught in plankton tow.

Sandlance is important in northern seas as food for larger animals and is plentiful along the coast from Cape Cod to Cape Sable wherever there are sandy shores (Bigelow and Schroeder, 1953). They form large schools near the water's surface where they are vunerable to predation from whales, birds and fish. They also bury themselves in sand (The scientific name translates to "sand diver"). They feed on small crustaceans, especially on copepods and on small fish fry (Scott, 1988). They also eat worms. (Bigelow and Schroeder, 1953). The larvae are abundant in Europe from January to March (Bigelow and Schroeder, 1953). There is a commercial fishery for sandlance.

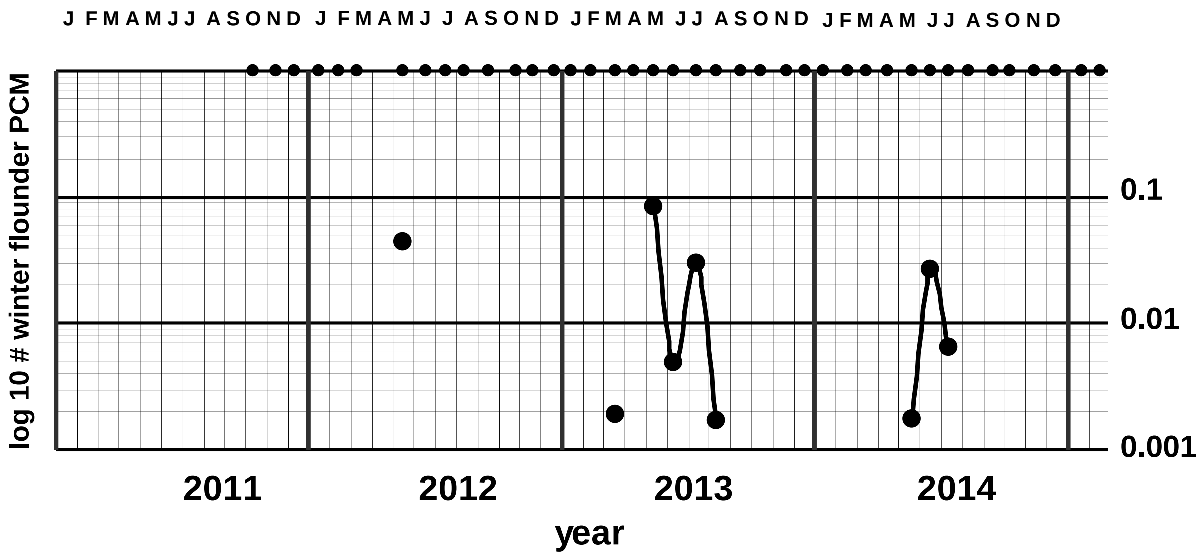


Figure 137. Winter Flounder; ***Pseudopleuronectes americanus*** larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Most winter flounder larvae were caught in summer. They were present in spring and fall as well.

Figure 138. Winter flounder, ***Pseudopleuronectes americanus*** (Walbaum) 1792, caught in plankton tow

Wniter flounder is a commercially important fish species. Unlike other local flatfishes, winter flounder eggs sink to the bottom in clusters and take two to three weeks to hatch. The larva grows to five mm and the yolk is absorbed by about two weeeks of age (Bigelow and Schroeder, 1953). According to Sullivan (1914) diatoms are the first meal of the larva once the yolk sac has been absorbed. Later they would feed on small crustaceans and Sullivan (1914) usually found isopods in the stomachs of post metamorphosis fry. Young flounder in Casco Bay were found to feed on isopod crustaceans with smaller amounts of copepods, amphipods, crabs, shrimp and worms (Bigelow and Schroeder, 1953). Younger fish can withstand a wide range of temperatures (Scott, 1988). They are preyed upon by other fishes, seals, ospreys, blue herons and cormorants (Scott and Scott, 1988).

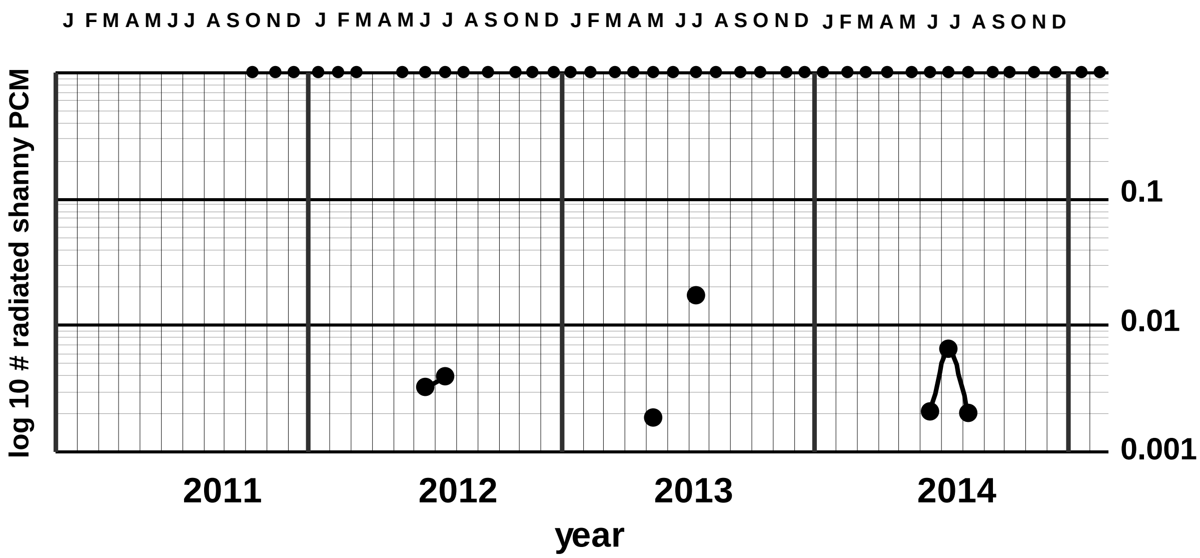


Figure 139. Radiated shanny larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Larval radiated shanny were seen in June and July in 2012, in May and July in 2013 and between June and August in 2014. They were not seen in the historical series until April and May of 1968 and those are the only two observations.


Figure 140. Radiated Shanny, ***Ulvaria subbifurcata*** (Storer) 1839, larva caught in coarse mesh net.

The radiated shanny is common in the Bay of Fundy and has been found near low tide mark under stones on more exposed shores. According to Scott and Scott (1988) they spawn in early summer. Eggs of this species have not been seen but larvae have been sampled by tow nets in June, July and October (Bigelow and Schroeder, 1953). Larvae drift in surface water until about seven mm long (Scott and Scott, 1988).

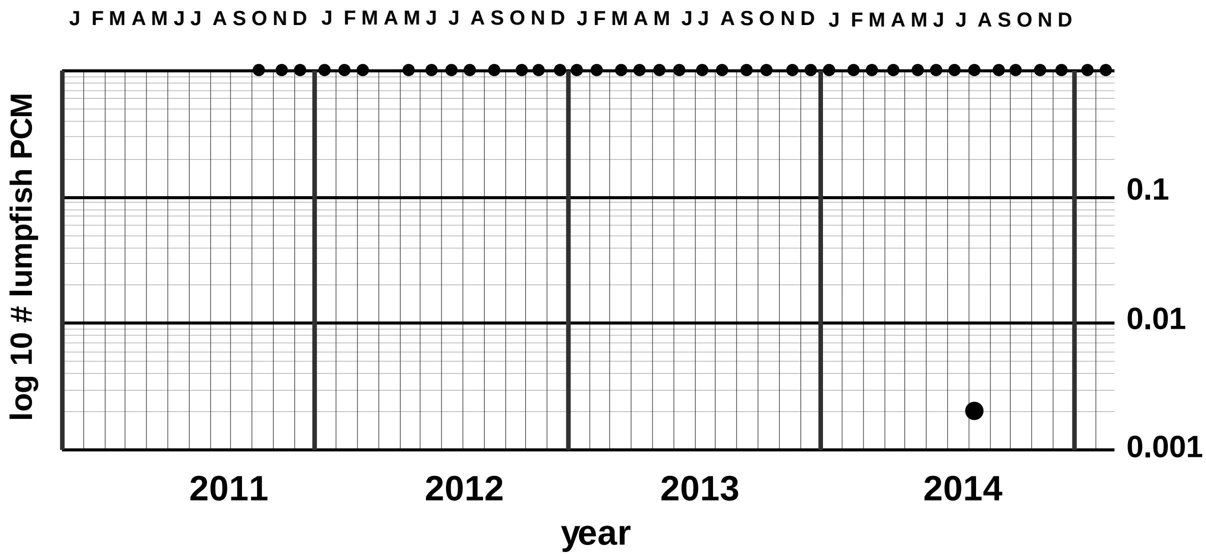


Figure 141. Lumpfish; ***Cyclopterus lumpus*** juvenile density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Figure 142. Juvenile lumpfish, ***Cyclopterus lumpus*** Linnaeus 1758, caught in plankton tow.

The lumpfish has a ventral sucking disc formed by the pelvic fin and this fish has been associated with floating patches of seaweed (Scott and Scott, 1988). Spawning occurs in shallow water in early spring (Scott and Scott, 1988). During the spawning season males turn reddish in colour, while females become blue-green. There is a general movement into shoal waters at spawning time followed by an offshore movement afterward. Small larvae have been found in the Gulf of Maine in early spring (Scott and Scott, 1988). Adult lumpfish feed on ctenophores, jellyfish, small fish, and a variety of small invertebrates (Bigelow and Schroeder, 1953). Juveniles caught in the Bay of Fundy were about fifty mm long and were thought to be about a year old (Scott and Scott, 1988). The young lumpfish that we caught is just over twenty mm long.

There is a small commercial fishery; lumpfish are eaten in Nordic countries and their roe is used as inexpensive caviar.

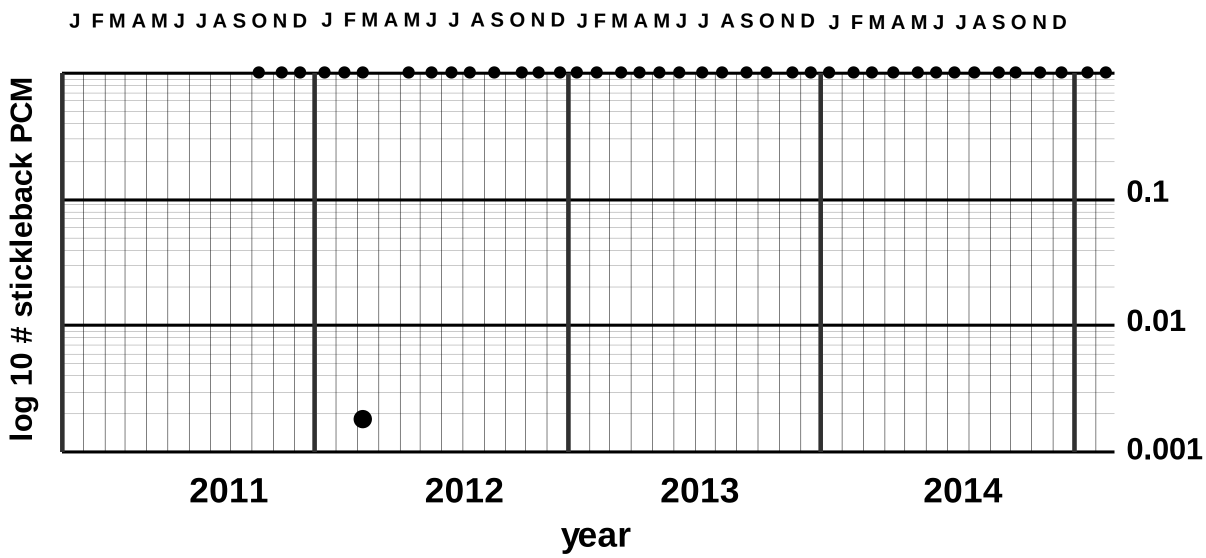


Figure 143. Three spine Stickleback; ***Gasterosteus aculeatus*** adult density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

There was one three spine stickleback observed in March of 2012.

Figure 144. 3 spine Stickleback, ***Gasterosteus aculeatus*** (Linnaeus) 1758, adult from coarse mesh tow. This summer spawner is a nest builder and feeds mainly on copepods, euphausiids and isopods (Scott and Scott, 1988).

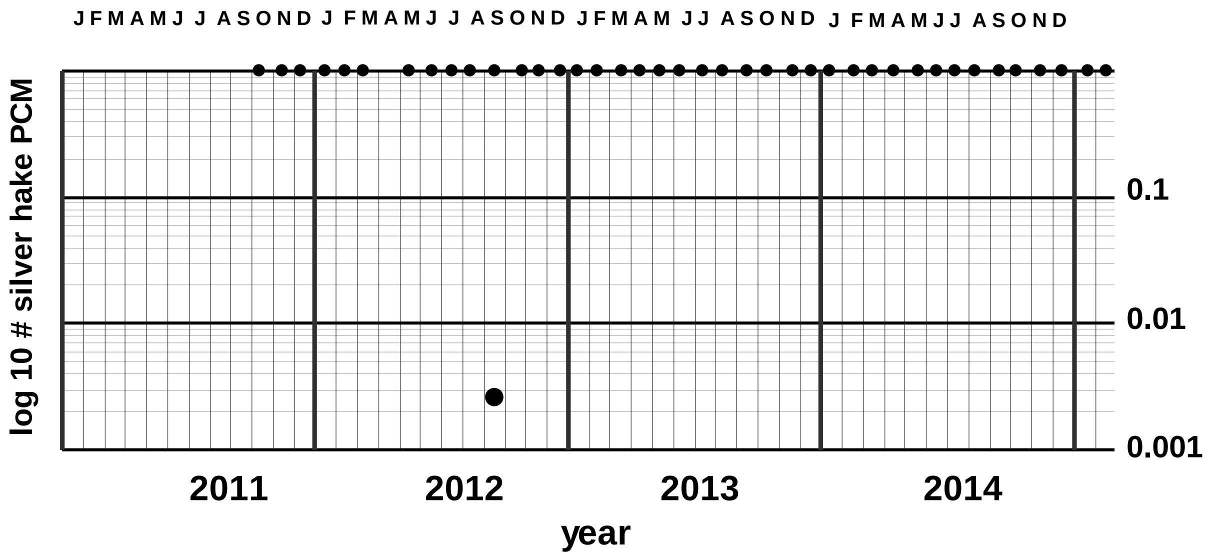


Figure 145. Silver Hake, ***Merlucius biliniaris***, larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

A single silver hake larva was sampled in September of 2012. The only other specimen from the historical series was captured in September of 1963.

Figure 146. Silver Hake, ***Merlucius biliniaris*** (Mitchill) 1814, larva caught in Prince 6 plankton tow.

Silver hake is a marine fish found along the west coast of the north Atlantic Ocean. Spawning of this commercially fished species in the Gulf of Maine occurs from June to September when buoyant eggs are released Scott and Scott, 1988). Larvae are two and one-half to three and one-half mm long when they hatch and are planktonic for three to five months (Scott and Scott, 1988). They are swift swimmers and voracious predators that probably eat the young of practically all the common Gulf of Maine fishes. Egg production occurs between July and August (Bigelow and Schroeder, 1953). Silver hake feed on smaller fish and crustaceans.

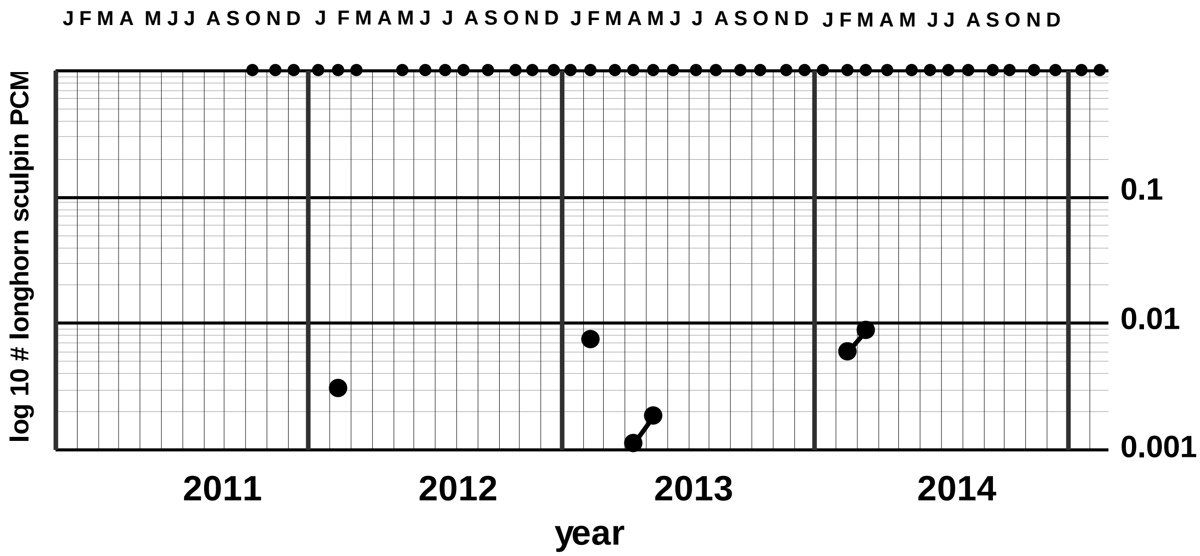


Figure 147. Longhorn sculpin, ***Myoxocephalus. octodecemspinosus*** (Mitchill 1815, larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Larvae of longhorn sculpin were observed in the mid-winter season from 2012-2014 but not in 2015. In 2013 they were present during the first half of the spring season. These larvae were not encountered in the historical series until right near its end in March, April, May and July of 1968 and then once again the following March of 1969.

The longhorn is the most common sculpin in the Gulf of Maine but is thought only to spawn on the Nova Scotia side of Bay of Fundy and along the coasts of Maine and Massachusetts (Bigelow and Schroeder, 1953). The eggs, about eight thousand from a thirty cm female, sink and are very sticky for the first day and cling together in clumps. The young fry have been taken in February and March off southern New England (Bigelow and Schroeder, 1953). Crabs and amphipods were the most common food items (Scott and Scott, 1988- referencing Morrow, 1951).

Figure 148. Larval ***Myoxocephalus. octodecemspinosus*** (Mitchill) 1815, caught in Prince 6 plankton tow.

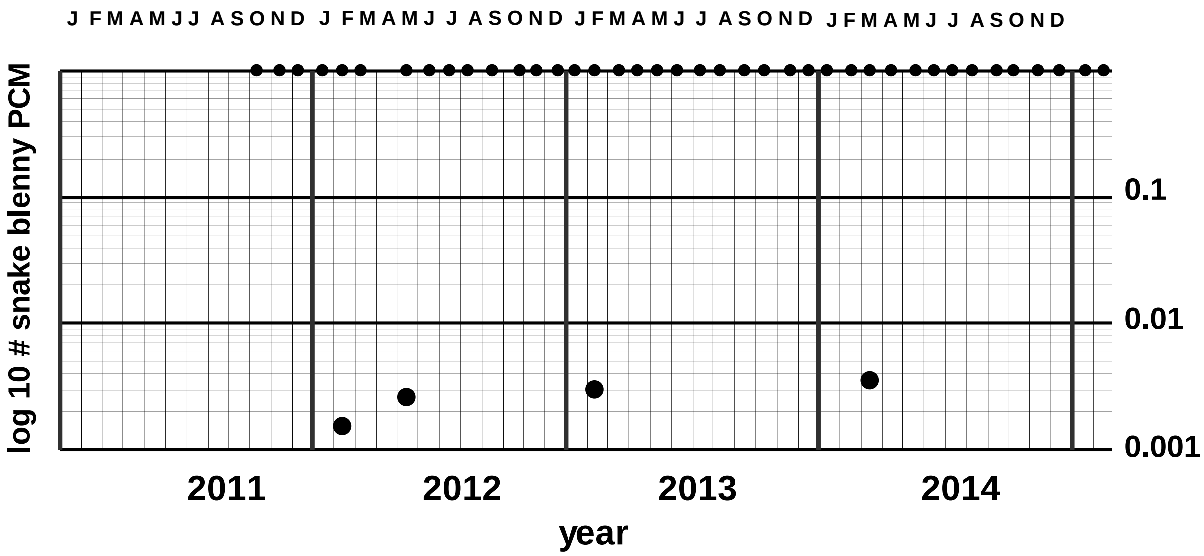


Figure 149. Snake Blenny larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Snake blenny larvae were found in winter of 2012-2014 and spring of 2012. This fish was not encountered in the past series until March of 1961. The following month there were six caught in one tow. Excluding 1962 and 1967, snake blenny larvae were found in every year up to and including 1970. They were observed between the months of January and June but most often seen in March and April.

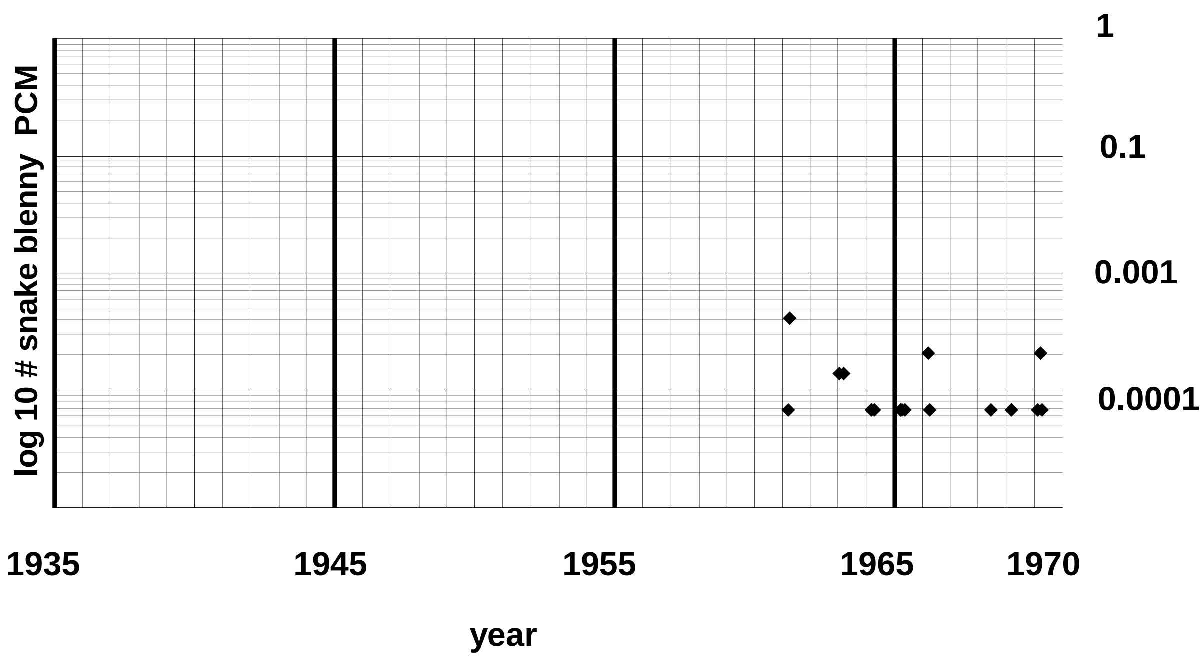


Figure 150. Snake blenny larval density from coarse mesh subsurface plankton tow series from 1937-1970.

Figure 151. Snake blenny, ***Lumpenus lumpretaeformis*** (Walbaum) 1792, caught in Prince 6 plankton tow.

“The eggs of this species have not been seen, but they probably sink and stick together like those of the rock eel.” (Bigelow and Schroeder, 1953) This species is common in Passamaquoddy Bay (Scott and Scott, 1988).

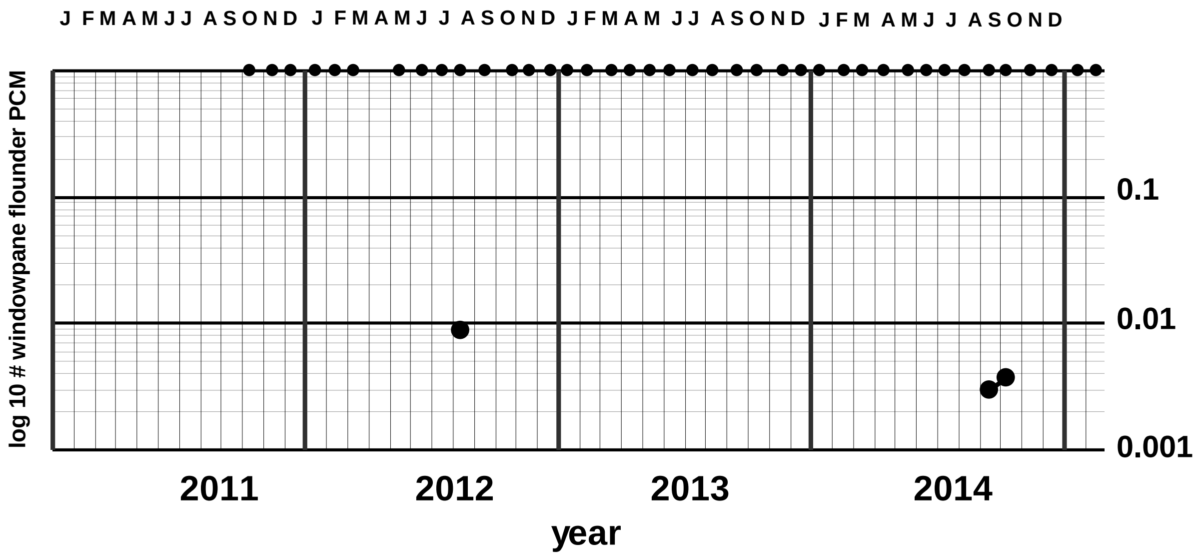


Figure 152. Windowpane Flounder; ***Scophthalmus aquosus*** larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

The larvae of windowpane flounder were observed in August of 2012 and in September and October of 2014.

Figure 153. Windowpane Flounder; ***Scophthalmus aquosus*** (Mithill, 1815), larva caught in Prince 6 plankton tow.

There is no evidence of seasonal movement of this flatfish (Scott, 1988). They are uncommon in the lower area, but common at the head of the bay in Minas Basin and Passamaquoddy Bay (Scott and Scott, 1988).

Spawning is in late spring and early summer when spherical, transparent and buoyant eggs are released. Incubation takes about a week and larval development is more rapid than for other flatfishes (Bigelow and Schroeder, 1953).

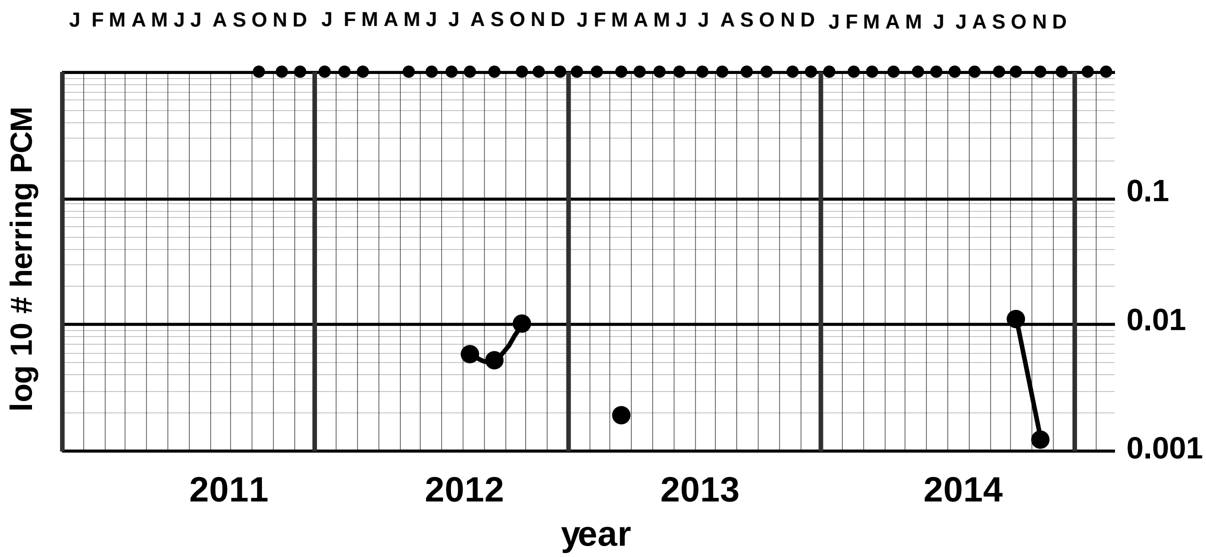


Figure 154. Herring; ***Clupea harengus*** larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Herring larvae were observed in the spring of 2013, late summer and early fall of 2012 and in the fall of 2014. They were observed twenty-one times in the historical series starting in October of 1940. In 1943 there were two larvae caught in the sample from September twenty-third and then single larvae caught in early and late September. In 1944 there were two cases of larvae caught in June and then on observations until December of 1949. In 1952 there were single larvae caught in June and November. The year 1954 has the greatest number of observations; March, June October and December. There is one observation in January of 1959 and the next in December 1963 followed by September 1964 which is followed by September and October of 1968. In 1969 one larva is seen in December and in 1970 there is one in March.

Figure 155. Herring, ***Clupea harengus*** Linnaeus 1758, larva found in plankton sample.
They have traditional spawning grounds, usually close to shore or on offshore banks. A long lived herring could spawn twenty times or more. Herring ovaries and milt sacs can weight one-fifth of total body mass. Sinking eggs stick in layers or clumps to anything on the bottom and egg masses can be enormous.

Incubation lasts about two weeks and the larvae hatch at five to six mm long. They grow at a rate of about one mm per week and lose their small yolk sac at about ten mm total length. They feed on phytoplankton as larvae (Scott and Scott, 1988) and then eggs and larval stages of copepods, bivalves and other plankton taxa (Bigelow and Schroeder, 1953).

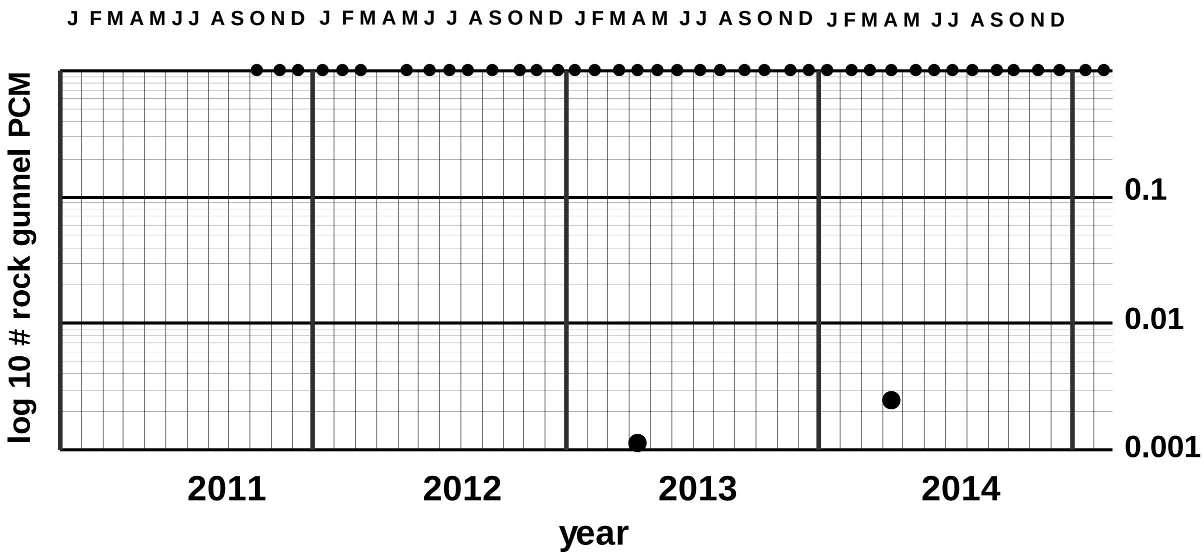


Figure 156. Rock Gunnel larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Rock gunnel larvae were observed in April of 2013 and 2014. They were caught in all months in the historical series and were common in the samples from 1937 to 1944 but were not seen from 1945 until September of 1950 and not seen again until June of 1957 after which they were seen every two years for about a year until 1970.

Figure 157. Rock Gunnel, ***Pholis gunnellus*** (Linnaeus) 1758, caught in the coarse mesh net.

Spawning occurs between November and January, when between eighty and six hundred eggs are laid on the sea bed in a large clump under a stone or in an empty bivalve shell, which is closely guarded until hatched. Incubation takes eight to ten weeks in European waters. The young fish drift near the surface until thirty or forty mm long and then sink to bottom. The rock gunnel avoids mud bottom and feeds on small crustaceans, polychaetes, molluscs and fish eggs Scott and Scott, 1988). Rock gunnel can breathe air when out of water. (Bigelow and Schroeder, 1953).

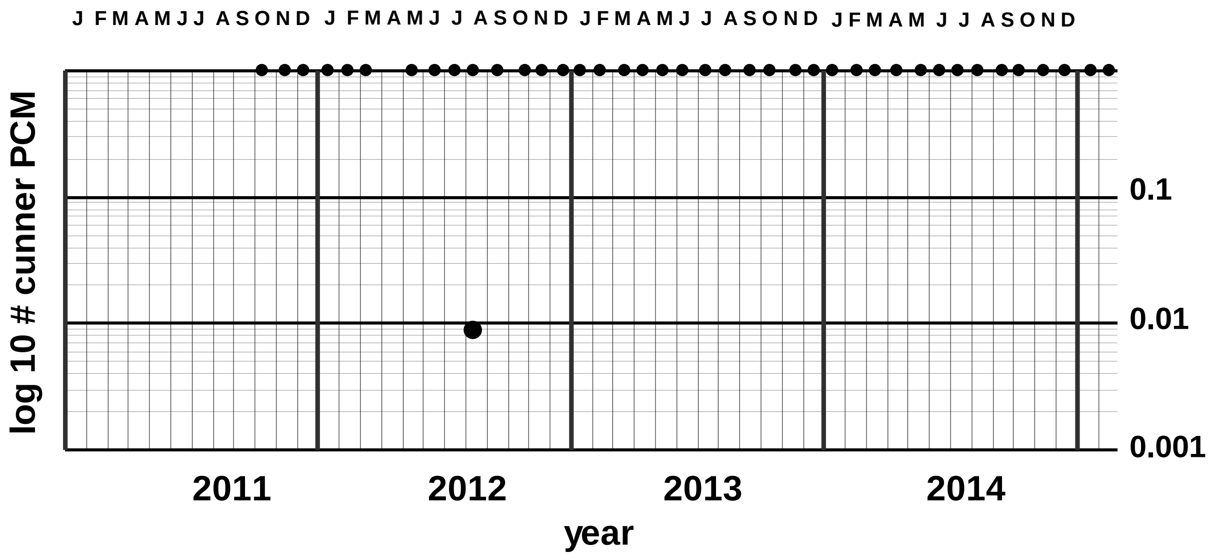


Figure 158. Cunner ***Tautogolabrus adspersus*** (Walbaum) 1792, larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

All specimens were caught in the same tow in August of 2012.

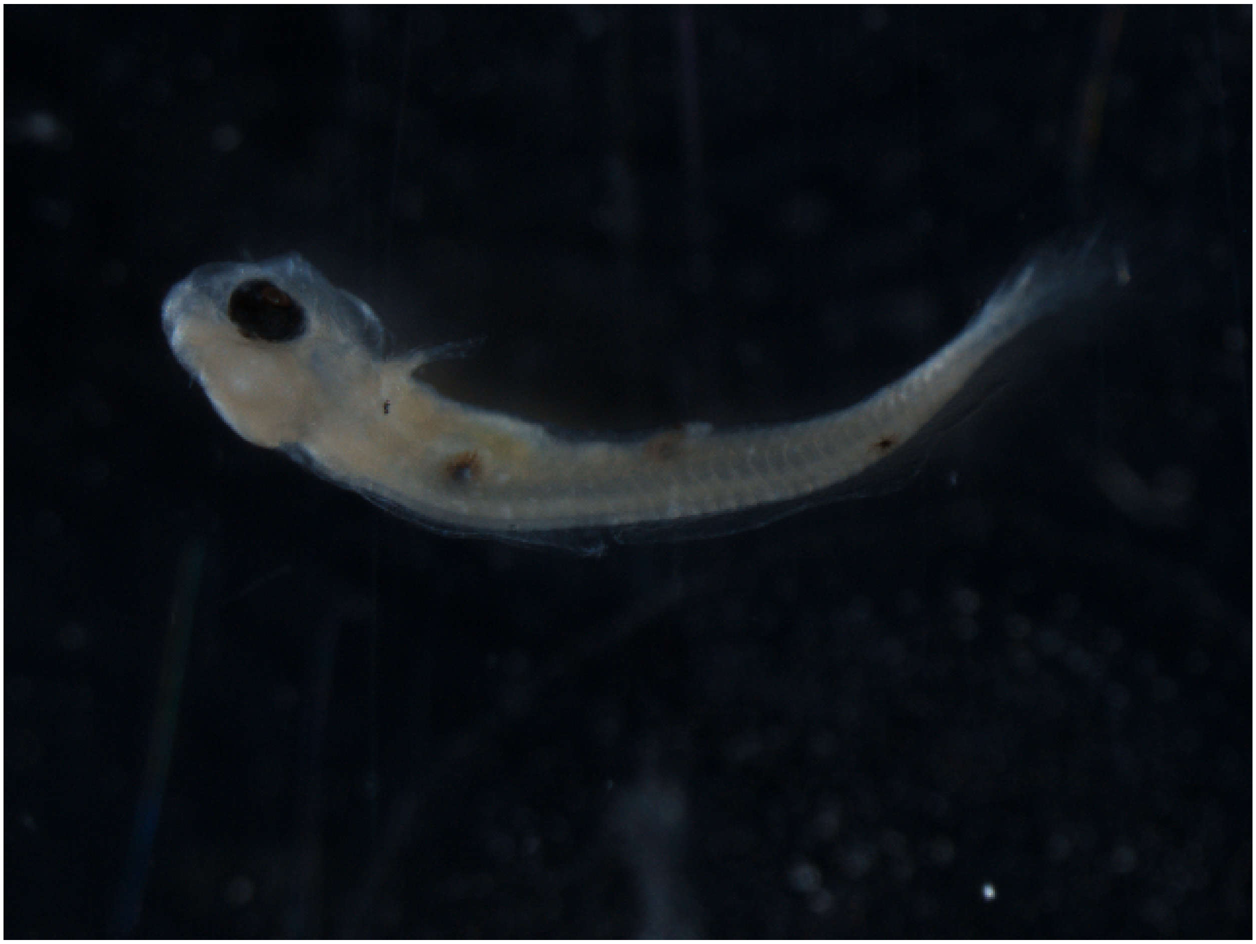


Figure 159. Cunner ***Tautogolabrus adspersus*** (Walbaum) 1792, larva found in plankton sample.

The cunner spawns between late spring and early summer with eggs that are buoyant, transparent and without an oil globule. The incubation period is less than a week and, at hatching, the larva is less than three mm long. “Little spawning occurs in the colder Bay of Fundy and few fry have been found here.” (Scott and Scott, 1988). They are often found in shallow water near submersed structures, such as wharves, wrecks, and seaweed beds. They are omnivorous, eating eelgrass as well as shellfish and crustaceans of all kinds (Bigelow and Schroeder, 1953).

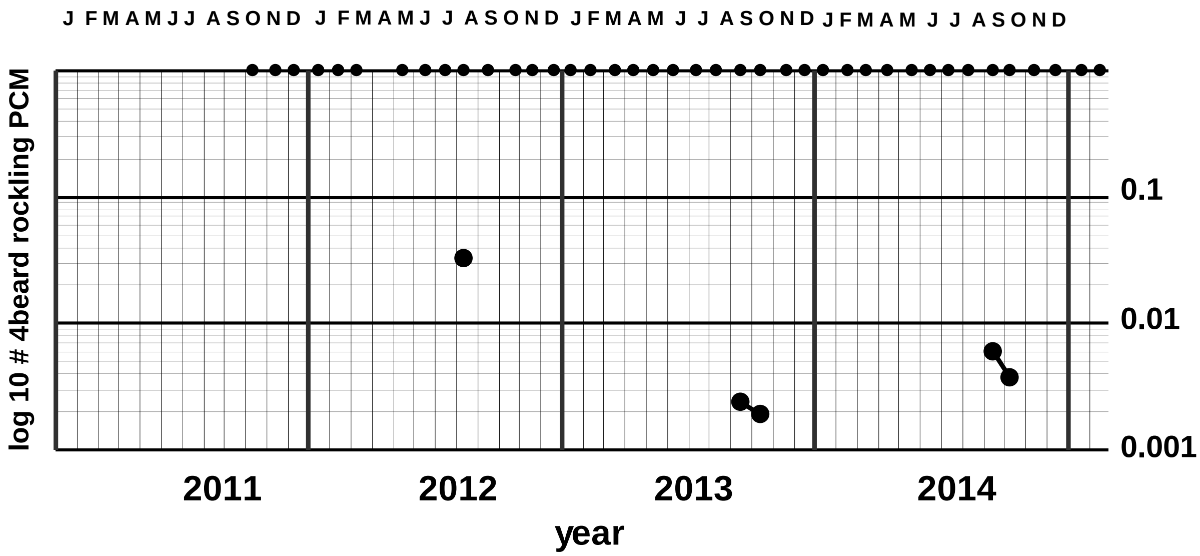


Figure 160. Fourbeard Rockling; ***Enchelyopus cimbrius***; larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Fourbeard rockling larvae were observed in August of 2012 and in September and October of 2013 and 2014.

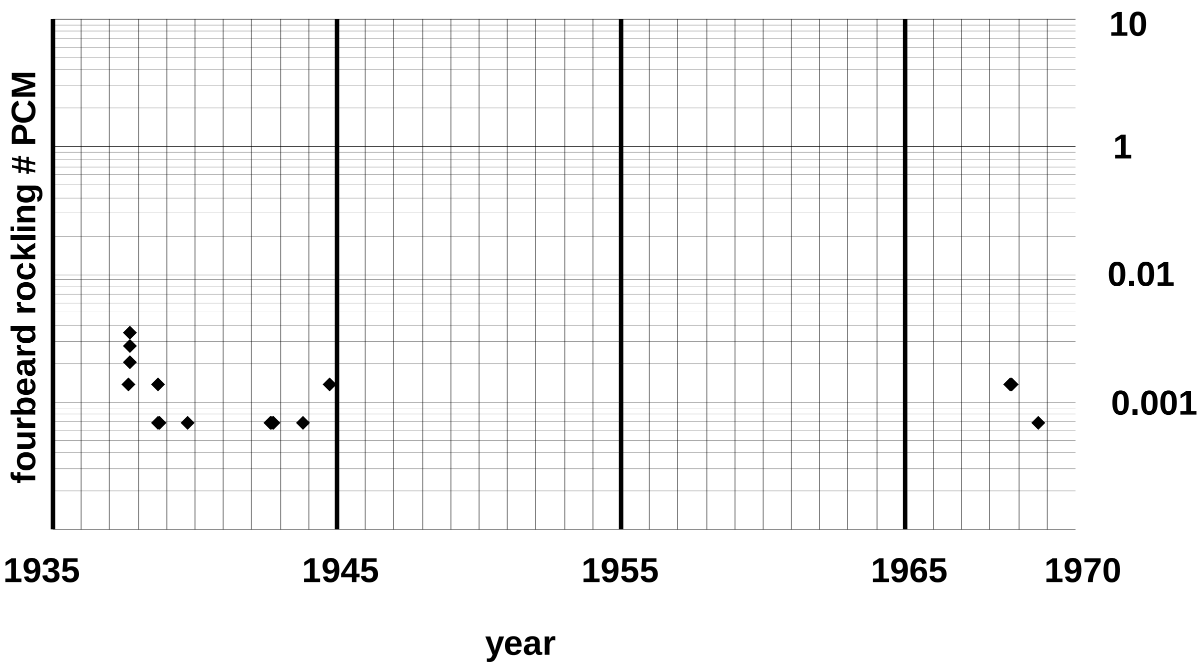


Figure 161. Fourbeard rockling larval density from coarse mesh subsurface plankton tow series from 1937-1970.

These larvae were captured during the summer on eleven occasions between 1937 and 1944. They were not seen again for twenty-five years until 1968 and 1969.

Figure 162. Four-beard rockling, ***Enchelyopus cimbrius,*** (Linnaeus) 1766, larva caught in Prince 6 plankton tow.

Eggs of this species are less than one mm in daimeter and buoyant. Spawning peaks when water temperature reaches nine ot ten degrees Celcius and newly hatched larvae are little more than two mm long (Scott and Scott, 1988). The yolk is absorbed by the time the larva reaches three and two-thirds mm. The larvae and later fry are silvery as they drift at the surface for up to three months before seeking the bottom at a length of about forty-five mm and feed on flatfish and small invertebrates (Bigelow and Schroeder, 1953). Tyler (1971) classified this as a “summer periodic” resident of Passamaquoddy Bay as moves into Passamaquoddy in June and out again by December due, it is postulated to its prefference for a soft, muddy bottom (Scott and Scott, 1988).

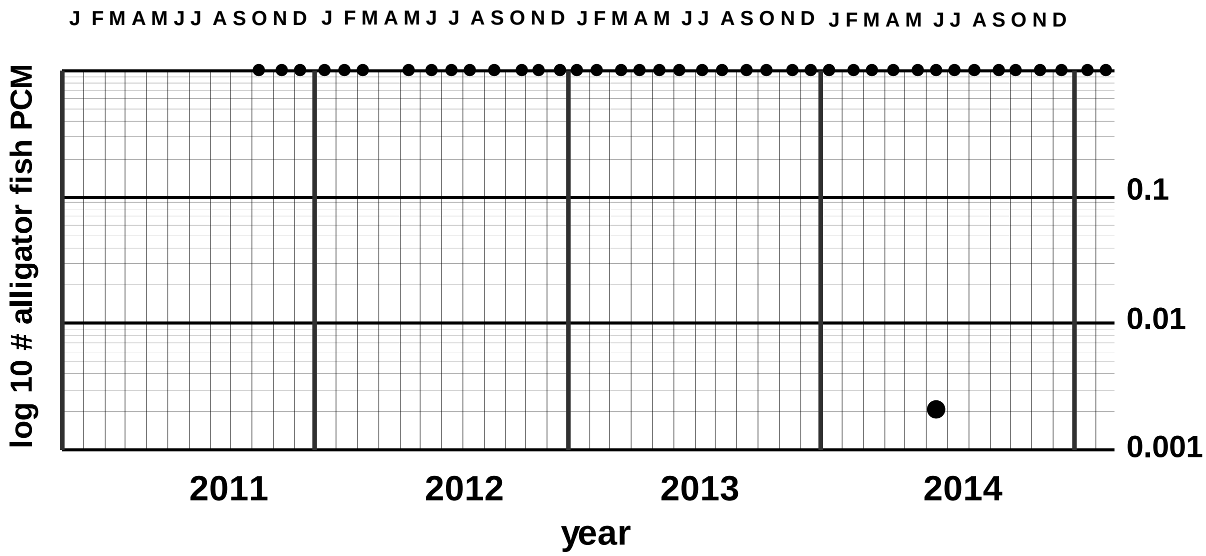


Figure 163. Alligatorfish; ***Aspidophoroides monopterygius*** juvenile density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

The alligatorfish was seen only once since October of 2011.

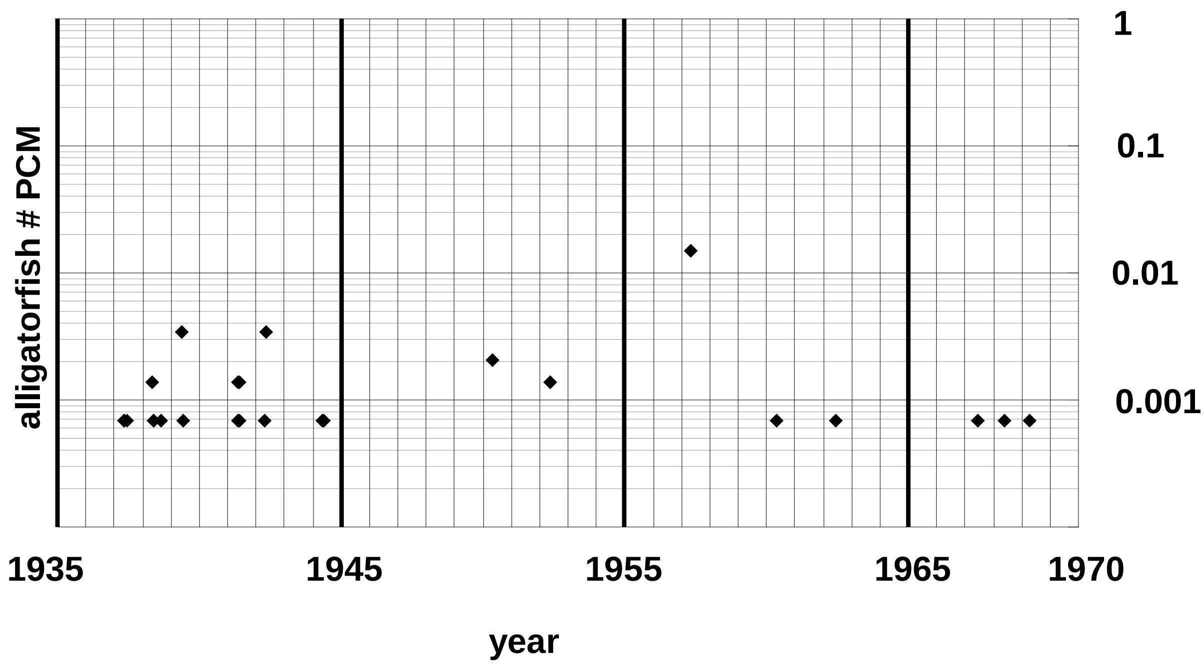


Figure 164. Alligatorfish density from coarse mesh subsurface plankton tow series from 1937-1970.

The alligatorfish was seen a dozen times between 1937 and 1944. During the next twenty-five years the alligatorfish was seen twice between 1945 and 1954, three times between 1955 and 1964 and three time between 1965 and 1970. In the spring of 1957 there were twenty-two alligatorfish caught in a single tow. Over the years this fish has been seen between April and October but most often during May and June

Figure 165. Alligatorfish, ***Aspidophoroides monopterygius*** **(**Bloch) 1786, juvenile

This species is one of numerous non-commercial marine fishes about which little is known of life history and biology. It has been hypothesized that this is a fish that spawns in mid to late autumn in the southern Gulf of St. Lawrence (Arbour et al., 2010). Larvae have been found in Passamaquoddy Bay from April to June according to Huntsman (Scott and Scott, 1988).

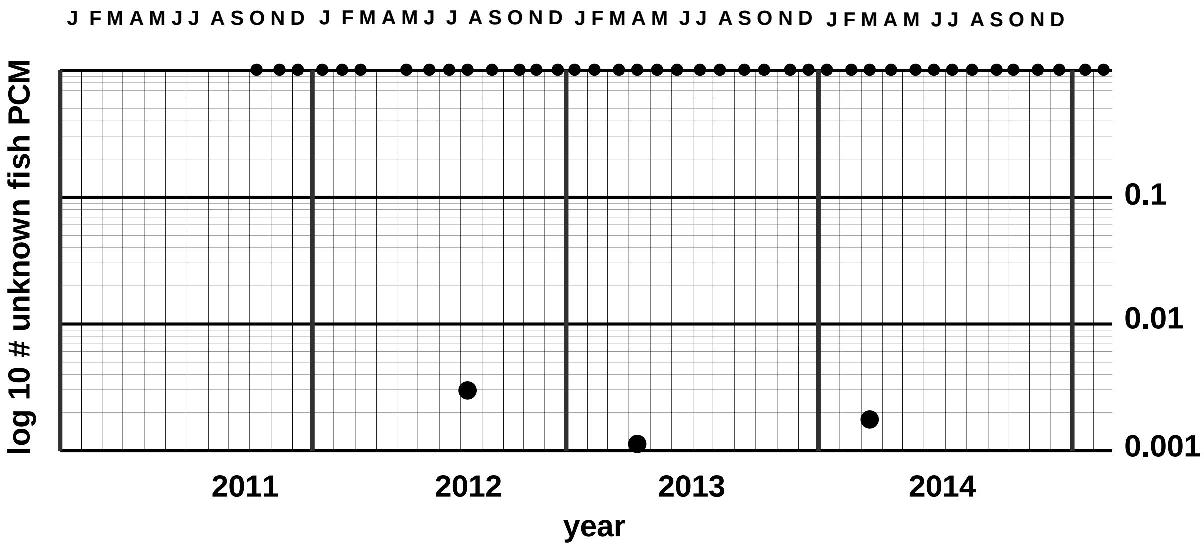


Figure 166. Unknown (damaged) fish larval density (number per cubic meter) from coarse mesh subsurface plankton tow. Sampling dates are marked along the top of the plot.

Type 2 predator

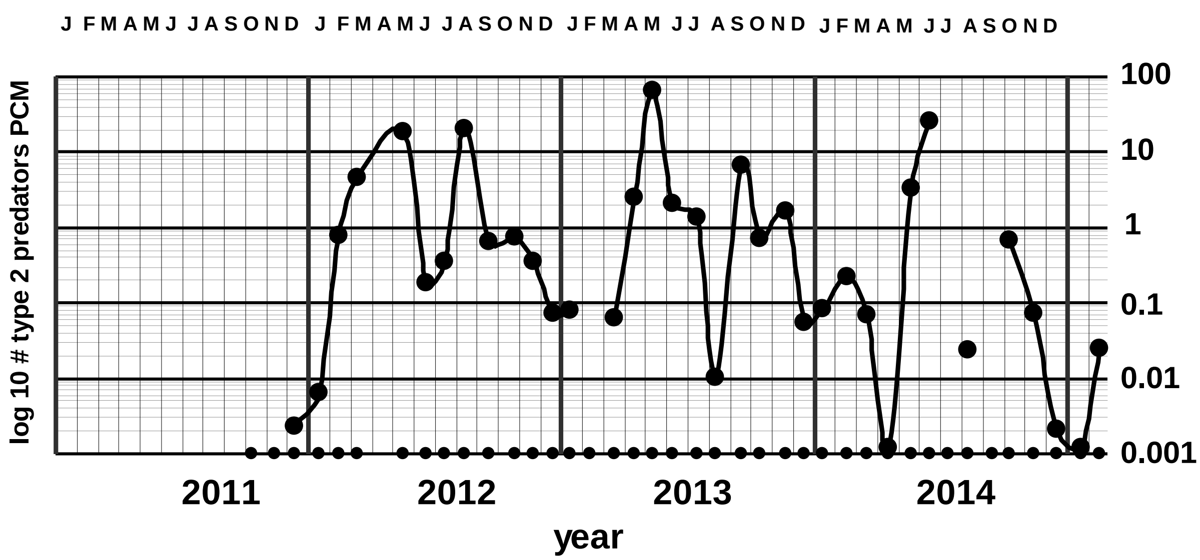


Figure 167. Type 2 predator density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Cnidaria make up the bulk of this group which also includes Ctenophora. Sampling dates are marked along the bottom of the plot.

Type 2 predators include cnidarians and ctenophores with annual peaks of density between ten and one hundred per cubic meter. There were two peaks in 2012, one in May and one in August. In May of 2013 a peak of almost one hundred jellies per cubic meter was observed. In 2014 highest density was in June.

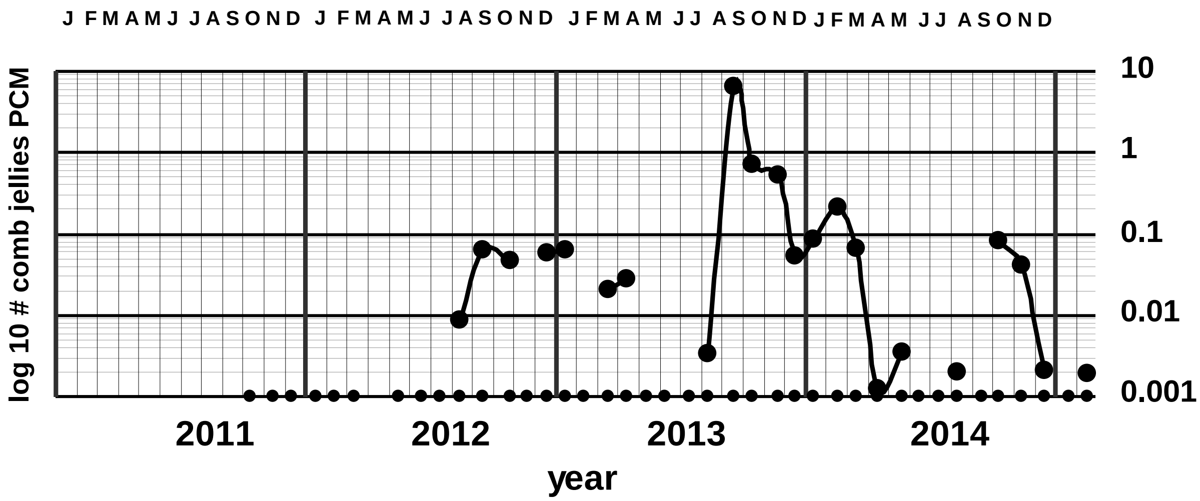


Figure 168. Comb jelly (Ctenophora) density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Ctenophores were not encountered in plankton samples until July of 2012 and, except for November, were seen for the remainder of the year. They were observed in eight months of 2013 with a peak density of almost 10 per cubic meter in September. They were observed in nine months of 2014. Since the fall of 2011, when ctenophores were not found at all, occurrence has increased to seventy-five percent of observations in 2014.

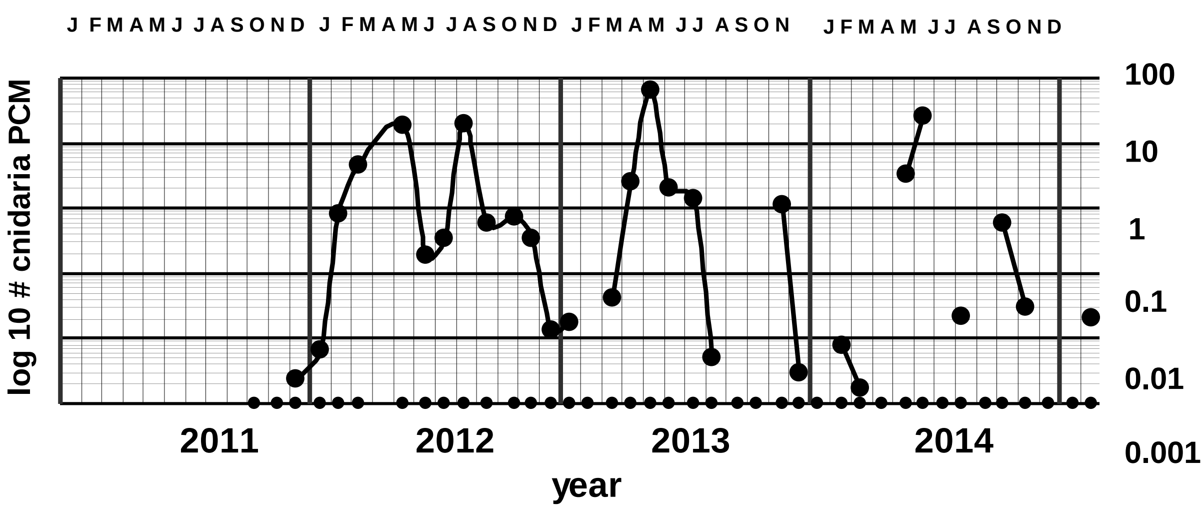


Figure 169. Cnidaria density (number per cubic meter) as estimated from coarse mesh subsurface plankton tow. Sampling dates are marked along the bottom of the plot.

Highest density was observed in spring and summer of 2012 and in the spring of 2013 and 2014. Cnidaria were observed in every month sampled in 2012 with a density above one tenth per cubic meters for nine months. In 2013 they were above one tenth per cubic meters for only five months and in 2014 for only two months. Since 2012 cnidarians have gradually become less frequent in the samples.

Settled volume

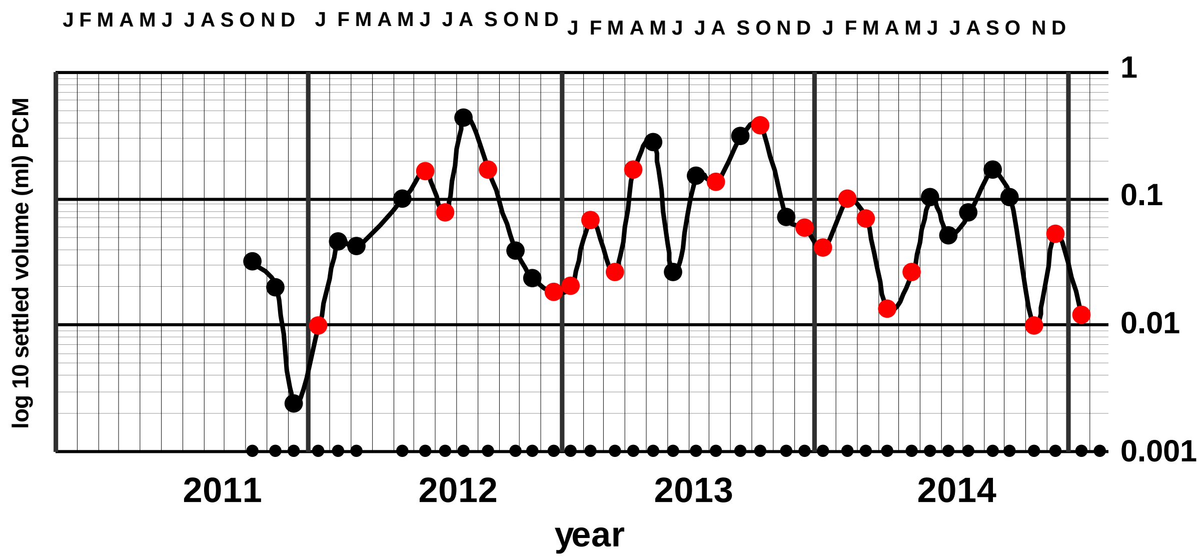


Figure 170. Settled volume (ml per cubic meter) as estimated from coarse mesh subsurface plankton tow. Jellies evident in the sample jars and those observations are marked in red.

Fall settled volume increased between 2011 and 2013 and October volume continued to increase in 2014. Overall, annual average settled volume was less than that observed in previous years.
Jellies were not seen in the jars of samples from the fall of 2011. Jellies were evident in five sample jars from 2012 but April was not sampled. In 2013 and 2014 jellies were evident in seven samples. From 2012 to 2015 jellies were evident in January samples.

CONCLUSIONS:

As figure 171 shows, annual surface temperature varies by almost twenty degrees Celcius and surface salinity may, at times, be reduced to one-third of normal. Large variability in hydrographic conditions found at the surface limit the variety of zooplankton to the more eurythermal and euryhaline, those able to tolerate a wide range of temperature and salinity.

One of the most striking differences between historical and contemporary catches of zooplankton is that there are more observations of larvaceans than in the past. This may indicate that there is more particulate material of the size preferred by mucous feeders than in the past.

Over the past four years the plankton catches have increased slightly with copepods, euphausiids, cladocerans, pteropods, larvaceans, arrow worms and the larvae of copepods, euphausiids, barnacles and bivalves all showing an increasing trend of peak density.

This monitoring station is best characterized by the zooplankton inhabiting its water column throughout the year. A summary of record catch density of each taxon from the three kinds of zooplankton tows since 2011 and comparison with historical catch data is shown in table 4. Observations on seasonal trends in density and occurrence over the past four years are also included in order to make comparisons between the three plankton tows.

Table 4. Summary and comparison of three tow types for all taxa identified. The record high density for each taxon is given as number of individuals per cubic meter (PCM). Trends over the past four years in the phenology of each taxon are noted along with whether they are becoming more or less common in the samples.

taxon and historical observations	**fine mesh vertical tow recent observations**	**fine mesh tow recent observations**	**coarse mesh tow recent observations**
calanoid copepods Copepods reach peak density around September and numbers decrease rapidly through October and November. Small numbers are found in December (Legaré, 1961). **historical %** of total catch number for 1957 and 1958 Quoddy Project (Legaré and Maclellan, 1959). **1. 50% *Acartia (Acartiura) clausi*** Giesbrecht, 1889 Observed in eighty-nine percent of all tows. It was most dense from June to October. **2. 20% *Tortanus sp.*** Observed in eighty-four percent of the	calanoid copepods Aug 2014 20000 PCM Observed in all seasons with a slightly increasing trend. Steady increase in numbers from January through to July of 2013.	calanoid copepods Aug 2011 100000 PCM Observed in all seasons. There has been an increasing trend since 2012. Steady increase in numbers from January through to August of 2013.	calanoid copepods Sep 2014 200 PCM Observed in all seasons with an increasing trend of peak density between July and September. In 2013 the catch number increased steadily from January through to July and then increased again in September.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
tows and increased in numbers from April through September and then declined over the rest of the year Legaré, 1961). This estuary was found to be the centre of abundance in the Quoddy region by Legaré and Maclellan (1959). **3. 13% *Eurytemora herdmani*** Thompson I. C. & Scott A. 1898 Observed in sixty-four percent of the tows. It was found in all months in the vertical tows with a peak in population in summer however an unusually large pulse was observed in February of 1937 (Legaré, 1961). **4. 6% *Pseudocalanus minutus*** (Kroyer, 1845) Observed in sixty-seven percent of the tows. Numerous from June to October in fine mesh fifteen minute tow (Legaré, 1961). Propagation begins in March and continues in a succession of			

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
generations until September (Willey, 1936). **5. 5% *Temora longicornis*** (Muller O. F., 1785) Observed in twenty-three percent of the tows and most numerous in the autumn (Legaré, 1961). **6. 4% *Calanus finmarchicus*** (Gunnerus, 1770) Observed in seventy percent of tows. Fish (1936) observed breeding in the Gulf of Maine, its western part being the main supplier to the Passamaquoddy area but propagation into the estuary is limited depending upon the season. McMurrich (1917) found it to be numerous from November through to April but only occasionally during the spring, summer or early autumn. Willey (1921) found it to be numerous during the winter of 1916-1917.			
Euphausiidae	Sep 2014 10 PCM	Oct 2014 1 PCM	May Jul 2012 1.5 PCM

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
Thysanoessa inermis (Kroyer, 1846) ***Meganyctiphanes norvegica*** (M. Sars, 1857) Maximum density in summer and autumn and eggs are also sampled. In 1944 there were no euphausiids observed (Legaré, 1961).	Observed in all seasons and becoming more common with a slight increase in density.	Rare.	Rare.
Mysinae ***Neomysis americana*** (S.I. Smith, 1873) ***Mysis mixta*** Liljeborg, 1853 From 1937 the first mysid was observed in September of 1944. They were not seen again until September of 1947 and then not until June of 1949 and September, 1950. No mysids were seen again in the series that Legaré (1961) examined up to 1959. Monitoring continued into the 1970's and mysids were sampled during the summer and fall of 1960 and from spring through to the fall for the next five years until 1965. In	Sep 2011 4 PCM Only one summer catch.	Sep 2011 1 PCM Only twice 2011 & 2013.	Sep2012 2 PCM Rare since 2012.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
1966 and 1967 they were observed in spring and summer and then in 1968 in late summer only.			
Cladocera ***Podon leuckartii*** (Sars G.O., 1862) ***Evadne nordmanni*** Loven, 1836 Both species were taken regularly in small pulses during the summer.	Aug 2011 1000 PCM Observed from late-spring to mid-fall. Peak density of cladocerans declined between 2011 and 2013. There was a ten fold increase in 2014.	Aug 2011 2014 2500 PCM There was a one hundred fold increase in peak density between 2013 and 2014.	Jun 2014 2 PCM Observed two or three times a year.
Cumacea	Apr 2012 0.1 PCM Only one spring observation.	May 2014 3 PCM Observed in Nov of 2013 and in May and September of 2014.	Nov 2013 0.1 PCM Three observations in 2012 and one each in 2013 and 2014.
Pteropod ***Limacina helicina*** (Phipps, 1774) Not found in autumn and winter and only occasionally in summer. McMurrich (1917) observed them from mid-June to September of 1916 in Passamaquoddy Bay. Fish and Johnson (1937) found them to be common in Passamaquoddy Bay during the month of August. ***Clione limacina***	Jul 2013 1000 PCM Observed in all seasons with an increasing trend in peak density. There was a ten to one hundred fold annual fall-winter decline and the 2012-2013 pattern of decline was different. None.	Dec 2014 1000 PCM Observed in all seasons with a gradually increasing trend. The last three spring peaks in April, May and June were increasing gradually. None.	Aug 2013 4 PCM Not observed in February or June. Peak density increased between 2011 and 2013 and then decreased the following year. None.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
(Phipps, 1774) Only eight specimens taken in February, March and April. McMurrich (1917) observed this species once on Feb 16 of 1916. Bigelow (1926) noted maximum density in Gulf of Maine to occur between February and May.			
Larvacea ***Oikopleura (vexillaria) labradoriensis*** Lohmann, 1892 ***Fritillaria borealis*** Lohmann, 1896 Larvacea were observed in May of 1940 and in June of 1938, 1941, 1942, and 1944.	Jun 2014 1000 PCM Observed in all seasons with a slight increasing trend. Becoming less common. There were two annual peaks in density; May and September of 2012, July and October of 2013, and finally, July and September of 2014	Oct 2013 500 PCM Common in 2012 and seen less frequently but at greater density since.	Jun 2014 1 PCM Most common in 2013.
copepod nauplius	Apr 2014 200 PCM Annual peaks had an increasing trend.	Aug 2014 300 PCM Annual peaks had an increasing trend.	Jun 2014 1 PCM Less common since 2012 with a decreasing trend of density peaks.
caligid copepod ***Lepeophtheirus salmonis*** (Kroyer, 1837)	None.	Jan 2013 2 PCM Observed in January and November of 2013 and 2014.	Jun 2012 0.01 PCM Observed in the fall and winter and less common since 2012.
decapod larva Zoea larvae of crabs occurred in spring, summer and autumn	Aug 2011 150 PCM Decreased after August. Peaks show falling trend.	Jul 2013 30 PCM Increasing from 2011 to 2013 and then decreasing in 2014.	Aug 2013 100 PCM Increasing from 2011 to 2013 and then decreasing in 2014.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
as successive waves and megalopa larvae were observed from March to November in small numbers.			
euphausiid larva The catch of juveniles was greater in summer than in the fall (Legaré, 1961).	Sep 2014 10 PCM Increasing trend of peaks in July through to September.	Aug 2014 35 PCM None in the fall. Increasing trend from 2012 to 2014.	Oct 2011 2 PCM Decreasing trend with none observed in 2013. Most common in 2014.
barnacle larva ***Semibalanus balanoides*** (Linnaeus, 1767)	May 2014 100 PCM Increasing trend of peaks; April of 2012, May of 2013 and March of 2014.	May 2014 1000 PCM Increasing trend of peaks and increasingly common.	Jun 2014 3.5 PCM Increasing trend of peaks and increasingly common.
bivalve larva Only a few individuals were recorded on each sampling occasion.	Aug 2011&13 1000 PCM Peak density in August in all years except 2012 when the peak was in July.	Apr 2013 2000 PCM Four nice peaks of one to two thousand occurring between late-spring and late-fall. The season was shorter in 2014.	Jun 2012 4 PCM A decreasing trend was observed since 2012 and they are becoming less common.
polychaete larva	May 2013 1000 PCM Springtime peaks in the last two years.	May 2014 40 PCM Slight increasing trend observed of May density peaks.	May 2014 5 PCM In 2012 larvae were observed in winter and spring; in 2013 they were observed in all seasons and in 2014 there were no summer observations.
echinoderm larva	Aug 2011 40 PCM No observations in 2014 and rare in the other years.	May 2013 15 PCM Only observed in May and June of 2013.	Sep 2012 0.1 PCM Not seen in 2014.
ascidian Larva Small autumn pulses of larvae were observed.	Feb 2012 15 PCM Small fall and winter pulses of larvae were observed.	Nov 2014 25 PCM Decreasing trend of fall and winter pulses from 2011 through to 2013. There was only one	None

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
		observation in 2014.	
facetotectan larva None in historical data.	Apr 2012 & 2014 4 PCM Observed in each April of 2012, 2013 and 2014 and in September of 2013.	Apr 2012 15 PCM Observed in April of 2012 and in January and April of 2014.	None
amphipoda Family Hyperiidae ***Hyperia galba*** (Montagu, 1815) Usually found as a commensal with ***Aurelia aurita*** ***Themisto compressa*** Goes, 1865 Rare at all times. McMurrich (1917) did not find it in the winter plankton at station Prince 6. Bigelow (1922) found this species to be an important element of the zooplankton over the outer part of the continental shelf from Halifax to New York. Family Gammaridae ***Calliopius laeviusculus*** (Kroyer, 1838) The most common species of gammarid amphipod, appearing frequently in spring and summer.	Aug 2014 5 PCM None observed between December of 2011 and September of 2013. Most common in 2014.	Dec 2012 3 PCM Observed decreasing trend.	Aug 2014 0.5 PCM Observed slightly increasing trend.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
chaetognatha ***Parasagitta elegans*** (Verill, 1873) Scarce in spring when diatoms flower. McMurrich (1917) found none in May with an increase in June and a fall season maximum. A record catch of two hundred young of this species was made in July of 1950. Huntsman and Reid (1921) observed that spawning in the Bay of Fundy occurs between the end of March and early September.	Oct Nov 2014 20 PCM Observed increasing trend of peaks in summer-fall.	Nov 2014 35 PCM Observed increasing trend of peaks in summer-fall.	Sep 2013 Nov2014 1PCM Observed increasing trend of peaks in summer-fall. Not observed in April, July and August of 2014.
polychaeta Family Sylliidae ***Myrianida*** Milne Edwards, 1845 Is also known as Autolytus; a constant resident and very evident from April to June. FamilyTomopteriidae ***Tomopteris (Johnsonella) catharina*** (Gosse, 1853) Found in only eight tows; five in October,	Aug 2011 30 PCM Observed in fall and winter.	May 2012 7 PCM Most observations were in fall and winter.	May June 2013 0.4 PCM Observed small summer and fall peaks of density. Peaks were smaller in 2014.

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
one in November, one in December, one in May and two in July.			
isopoda	Jul 2014 2 PCM Observed during the winter.	None	Aug 2014 0.01 PCM None observed in 2013. Two catches each in 2012 and in 2014.
ostracoda	Nov 2013 2 PCM Observed during fall and winter.	none	none
fish larva The larvae of commercial fishes were quite rare with occasional observations of gadoid, plaice, eel and smelt. Seventeen herring larvae were observed over the twenty three year series, ten in the fall and seven during the spring.	May 2013 0.2 PCM Observed in only four samples; one in 2014 and three in 2013.	Jun 2014 1 PCM Observed most often in winter and spring but may also be observed during summer. There was an increasing trend of density peaks between 2012 and 2014.	Jun 2014 1 PCM Observed in all months except December. An increasing trend of peak density was observed between 2012 and 2014.
Ctenophora ***Pleurobrachia pileus*** (O. F. Muller, 1776) Irregular pulses found in 9% of tows. Fish and Johnson (1937) reported August maximum in Passamaquoddy Bay. ***Beroe cucumis*** Fabricius, 1780	Aug 2012 10 PCM Not observed since the spring of 2014. none	Nov 2013 0.5 PCM Peak density was observed late in the year from 2012 through to 2014. Observed during the first four months of 2013 and 2014 but not in the first two months of 2015. There were no observations in 2011 and only two in 2012. none	Sep 2013 8 PCM Not observed until August of 2012 nor in any June or July. Fall peak in 2014 one hundred fold smaller than in 2013. none

taxon and historical observations	**fine mesh vertical tow recent observations**	**fine mesh tow recent observations**	**coarse mesh tow recent observations**
Rare; one catch in February, 1950 in coarse mesh subsurface tow. ***Bolinopsis infundibulum*** (O.F. Muller, 1776) Rare; large delicate jelly fragments upon net capture.	?	?	?
Cnidaria ***Aurelia aurita*** (Linnaeus, 1758) Found in late summer in Passamaquoddy Bay. Extensive schools were seen in the late summer of 1957 and 1958 (Legaré and Maclellan, 1959) ***Obelia sp.*** and others Short irregular pulses between March and June. ***Aglantha digitale*** (O.F. Muller, 1776) Stray individuals were observed in May, November and December according to Fish and Johnson (1937).	May 2013 1000 PCM Increased between 2011 and 2013 and then decreased in 2014.	May 2013 2000 PCM Peak density was observed in April 2012, May of 2013 and June of 2014.	May 2013 80 PCM In 2012 peaks were observed in May and in August and in 2013 there were peaks in May and November and in 2014there were peaks in May and October. They have become less common in the samples.
invertebrate eggs	Jul 2013 400 PCM Density peaks of two to four hundred observed	Jul 2013 800 PCM Density peaks of between one and eight hundred	Jun 2014 80 PCM Three observations in 2012. two in 2013 and

taxon and historical observations	fine mesh vertical tow recent observations	fine mesh tow recent observations	coarse mesh tow recent observations
	in August of 2011 and 2012, in July of 2013 and in June of 2014.	observed in August of 2011, in May and August of 2012, July of 2013 and June and September of 2014.	one in 2014.
fish eggs Small catches of pelagic fish eggs (mostly gadoids and flat fishes) were made during April, May and June with occasional observations of a few eggs in other months throughout the year.	Aug 2012 4 PCM Decreasing trend of peaks observed since 2012 and becoming progressively more common.	Aug 2011 2 PCM One observation in August of 2011, none in 2012, three catches in 2013, and four catches in 2014.	Jun 2014 1 PCM An upward trend in peaks was observed. Eggs were most common in 2013 and least common in 2012.
Liparus sp. sea snail or snail fish larva			Jan 2015 0.1 PCM Observed in all seasons except the fall and is the most common fish larva. The May or June peak density showed an increasing trend.
Ammodytes sp. sand lance larva			Mar 2013 0.01 PCM Observed in winter and in spring and becoming increasingly common.
Pseudopleuronectes americanus winter flounder larva			May 2013 0.1 PCM Observed in spring and summer and found to be most common in 2013.
Clupea harengus Atlantic herring larva			Oct 2014 0.01 PCM Observed in all seasons except the spring; August to Oct of 2012, October and November of 2014. A herring larva was also observed in March of 2013.

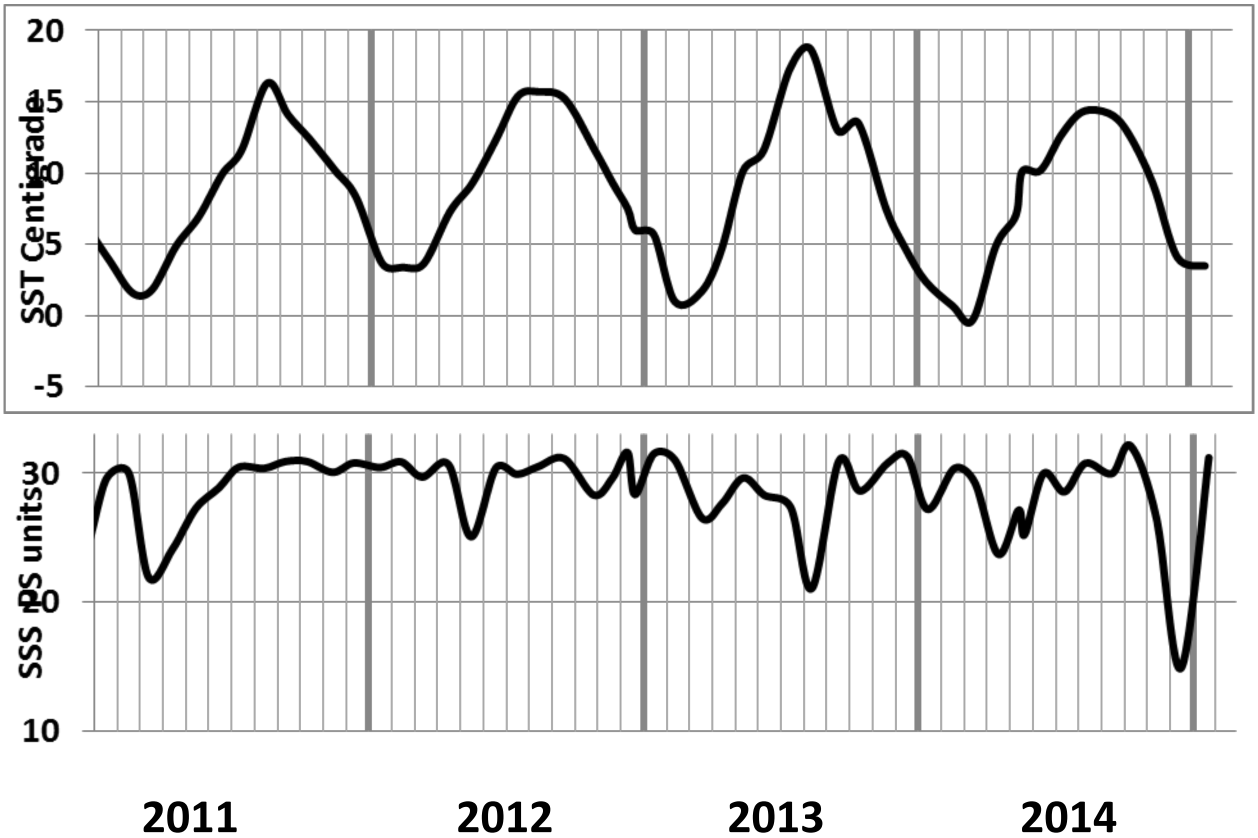


Figure 171. Time series of surface temperature and salinty at station Prince 6 over the past four years.

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