Kolarctic CBC – Project KO4178; Conserving our Atlantic salmon as a sustainable resource for people in the North; fisheries and conservation in the context of growing threats and a changing environment.

REPORT II. Graphs indicating long-term sea temperatures in the coastal areas in Northern Norway and in Northern Kola Peninsula (Russia); monthly and annual fluctuations with clear warming trends, simultaneous changes between monitoring areas and affects to ice break- up dates and timing of salmon catches in the River Tana watershed

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REPORT II. Graphs indicating long-term sea temperatures in the coastal areas in Northern Norway and in Northern Kola Peninsula (Russia); monthly and annual fluctuations with clear warming trends, simultaneous changes between monitoring areas and affects to ice break- up dates and timing of salmon catches in the River Tana watershed

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Mean monthly sea temperatures in Kola section in Kola Peninsula are at the lowest in April and May months. The lowest sea temperatures were close to 1.5 °C in the years 1966 and 1979. From the end of May, temperatures at sea started to warm towards the end of October. Sea temperatures started to cool from November towards May month. Temperatures in the depth of 0-200 meters have been between 2.5°-5.5°C in the end of June and July when salmon smolts are migrating from northern rivers to sea.

Monthly sea temperatures in the depth of 0-200 meters show clear periodic deviations from the long-term mean values. Deviations show periods when temperatures have been consecutively some years colder or warmer than the long-term mean temperature. Sea temperatures in thick water layers indicates that it has been clearly warmer summer months since the beginning of 2000's than the long-term mean temperatures since the year 1920. When the whole water mass between 0-200 meters has been warmer than the long-term mean temperature it will most probably increase plankton production and thereafter also crustacean production.

Sea temperatures in the depth of 0-200 meters indicate each year clear differences between June and July but not so clear differences between April and May, August and September.

Mean annual sea temperature at the depth of 0-200 meters is approx. 4.3°C in July, when salmon smolts are leaving their home rivers and enter the coastal areas. When salmon is in the post smolt phase in October-December, mean sea temperatures have been 4.9 °C.

Sea temperatures in Kola section are clearly higher in July in the surface layer (0-50 m) than in the deeper 0-200 m layer. Temperature conditions in this warmer upper layer might affect with a better survival of post smolts during their first months at sea. Also, later in the year in the period from October to December, sea temperatures are different between the upper surface and deeper water layers.

Sea temperature deviations from the long-term annual mean temperatures in surface layer and in deeper layer are clearly indicating colder and warmer periods. Cold period phase has been documented in Barents Sea area since the beginning of 1900´s and into the 1930´s. After that quite long-lasting cold period, there has been alternately clear colder and warmer periods in the sea temperatures. Sea temperatures have from the begin of 2000´s been clearly warmer in 0-50 meters and 0-200 meters, compared to the long-term annual mean. This warm period is exceptionally long compared to the durations of earlier warm and cold periods.

Sea temperatures in the surface layer are important for salmon. It is known that salmon smolts prefer the uppermost area of the water after they have descended from rivers to saltwater. Adult salmon is also using the uppermost layer when migrating towards its home river. Salmon fishermen have been using bend nets which are usually 7-15 meters in depth which indicates that adult salmon prefer swimming in warmer water during homing migrations. Salmon may face increased sea mortality ff sea temperatures continue to increase in the future, and especially during those periods which are vital for the survival of salmon smolts, for the growth of maturing salmon and for the food items salmon is using. Sea temperatures were in December in 1980´s approx. 3.5 °C and in the middle of 2010´s 5.5 °C. In May, when multi-seawinter salmon begins its homing migration along the northern coastal lines, sea surface temperature was in early 1980´s appr. 2 °C but, the temperature was 5 °C in the middle of 2010´s. This increase in temperatures is affecting the earlier homeward migration of multi-seawinter salmon.

Sea temperature and its annual fluctuation is the most important factor affecting the primary production at sea and thereafter reflecting into the fish production. Data indicates clear long-term fluctuations in the sea surface temperatures within the large northern coastal areas in Norway and in Russia, in each month of the year. These monthly fluctuations are taking place simultaneously between fjords and coastal areas. The Atlantic Golf-stream and its side streams transports during some periods of the year warmer and in other periods of year colder waters into the Barents Sea. It is noteworthy that sea surface temperatures are getting warmer or colder gradually along the years. This step-by step change in sea temperature can then cause gradual changes in primary production, crustacean production and in fish production.

It is well known that salmon stocks have considerable annual variations reflecting into the catch variations in coastal and river fisheries. Sea surface temperature at the time when smolts descends from rivers to the sea is an important and effective factor in regulating the size of salmon stocks. These smolts, or so-called post smolts, start their ocean feeding and growing period in the northern areas shortly after they have migrated from rivers to sea. This is a quite short time period (smolt window) lasting from middle of June to the middle of July. Post smolts are vulnerable to high predation during first months at sea but, optimal sea water temperatures with good nourishment has good affects on the size of salmon stocks.

Climate (air temperatures) in wider but also in local geographical area together with sea surface temperature in coastal areas are influencing the ice break-up dates, like it does in the River Tana. There has been synchrony between the days of ice break-up in the River Tana and the mean sea surface temperatures in May in Laksefjord and in Ingøy in Northern Norway. This clearly indicates that there are interactions between global increase in the climate (air temperatures) that has increased the coastal sea surface temperatures in the coastal areas in Barents region and these environmental factors together have affected the early ice break-up dates in recent years.

Sea temperatures have increased in May when large salmon usually has started to migrate close to the outer coastlines and fjords in the Finnmark area. The same long-term increase in the sea surface temperatures in autumn (mean temperatures in October-December period) can be observed.

Sea surface temperatures in outer coastal areas are in general lowest in Kola section from May to September when compared to temperatures in Laksefjorden, Ingøy and Vardø. Sea surface temperatures in Varangerfjord, however, are the coldest in the period from January to April when comparing to temperatures in Laksefjorden, Ingøy and Vardø.

Generally, between multi-seawinter salmon, three sea winter old salmon ascend earliest into the River Tana watershed. They start to migrate into the River Tana in late May but, the most important ascending period is the whole June month. It has been found that the ascending period nowadays has taken place earlier than in 1970´s. A reason for that is the fact that sea temperatures in Laksefjord have increased significantly in May month, reflecting from the same kind of warming of sea surface waters within a wider coastal area in Northern Norway, like in Ingøy. Combined into the higher sea water temperatures in North Norway late in spring, ice break-up has taken place earlier in the River Tana compared to ice breaking in 1970´s. There is a significant correlation between the median date of capture for the three sea-winter salmon caught in the river Tana and sea surface temperature at sea in May. There are also relations between sea temperatures in May and the median data of capture for previous spawning salmon. Previous spawning salmon is ascending into the River Tana even earlier than virgin 3 sea-winter salmon.

Key words:
Long term sea temperatures, Northern Norway, Kola, Tana, Atlantic salmon, salmo salar

Front page photo:
Eero Niemelä

Content

1. Sea temperatures at 0-200 meters depth in Kola section, Northern Kola Peninsula

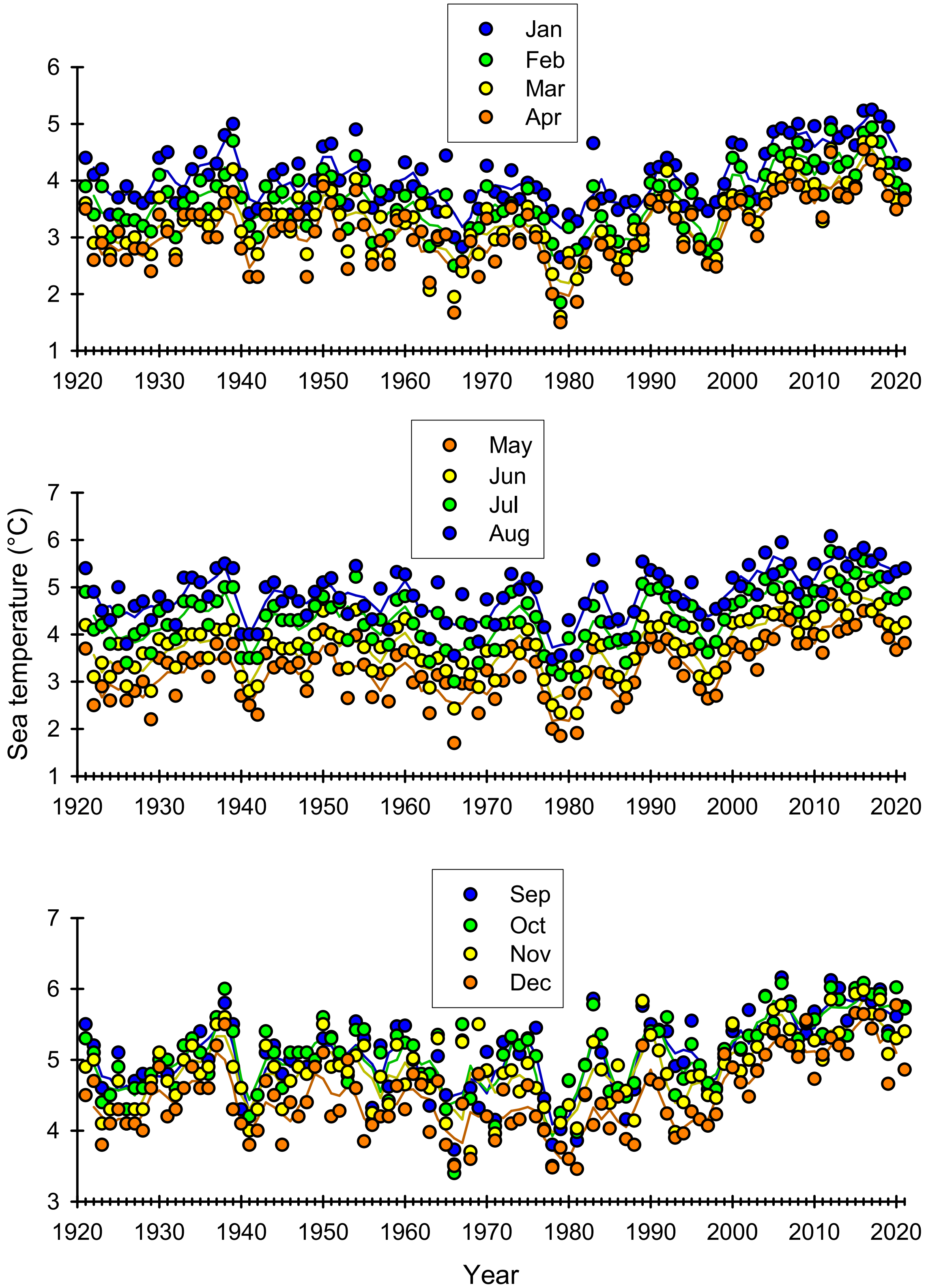

Figure 1. Long-term annual variations in the mean monthly sea temperatures from the year 1920 to the year 2021 in Kola section (st 3-7, 0-200 m) in Northern Kola Peninsula. Source; VNIRO (Russia).

Mean monthly sea temperatures in Kola section are the lowest in April and May months. The lowest sea temperatures were close to 1.5 °C in the years 1966 and 1979 (Figure 1). From the end of May temperatures at sea started to warm towards the end of October. Sea temperatures started to cool from November towards May month. Temperatures in the depth of 0-200 meters have been between 2.5°-5.5°C in the end of June and July when salmon smolts are migrating from northern rivers to sea.

Monthly sea temperatures in the depth of 0-200 meters show clear periodic deviations from the long-term mean values (Figure 2). These annual deviations are almost the same between each summer month. Deviations show periods when temperatures have been consecutively some years colder or warmer than the long-term mean temperature. Sea temperatures in thick water layer are indicating that it has been clearly warmer summer months since the beginning of 2000's than the long-term mean temperatures since the year 1920. When the whole water mass between 0-200 meters has been warmer than the long-term mean temperature it will most probably increase plankton production and thereafter also crustacean production.

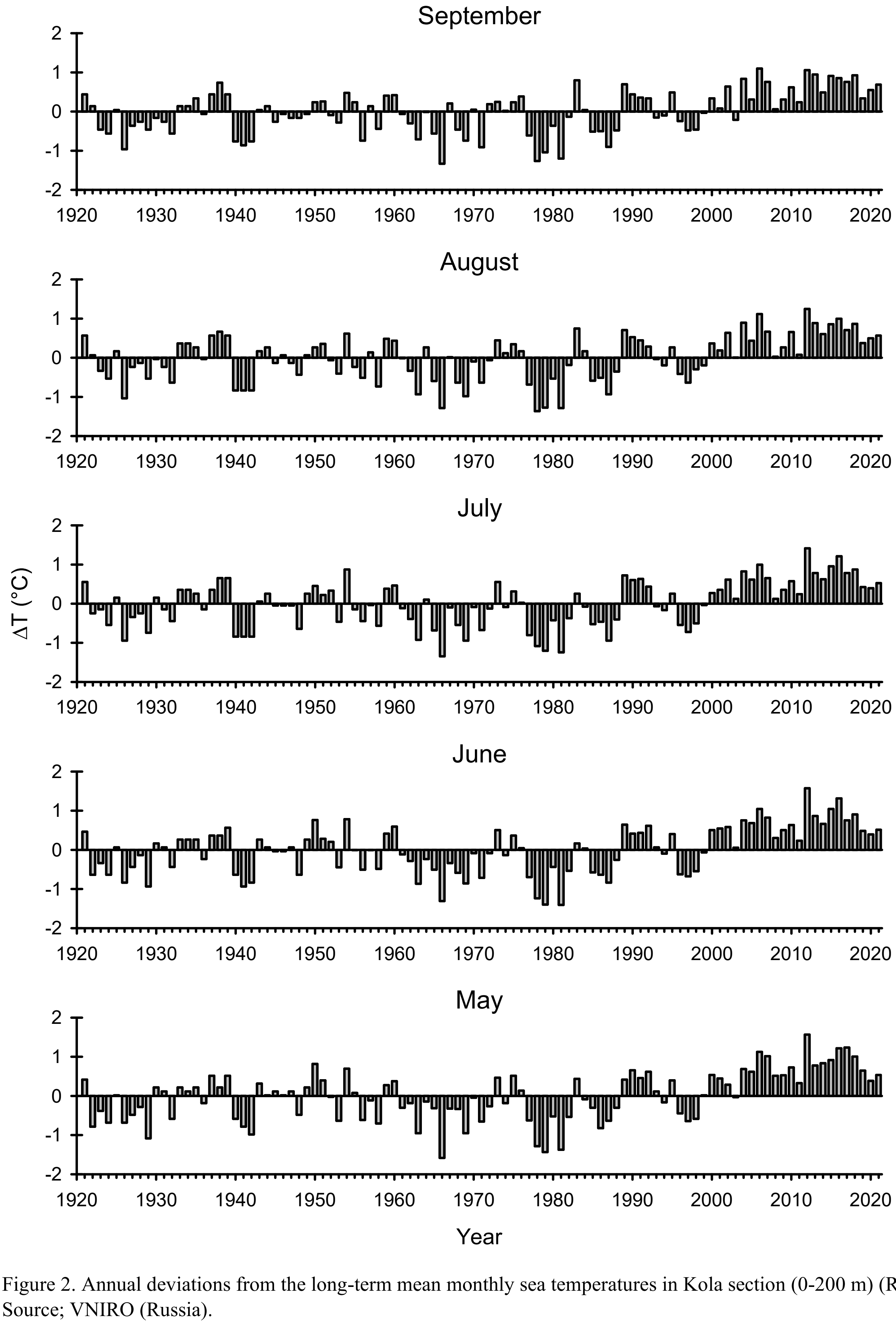

Figure 2. Annual deviations from the long-term mean monthly sea temperatures in Kola section (0-200 m) (Russia). Source; VNIRO (Russia).

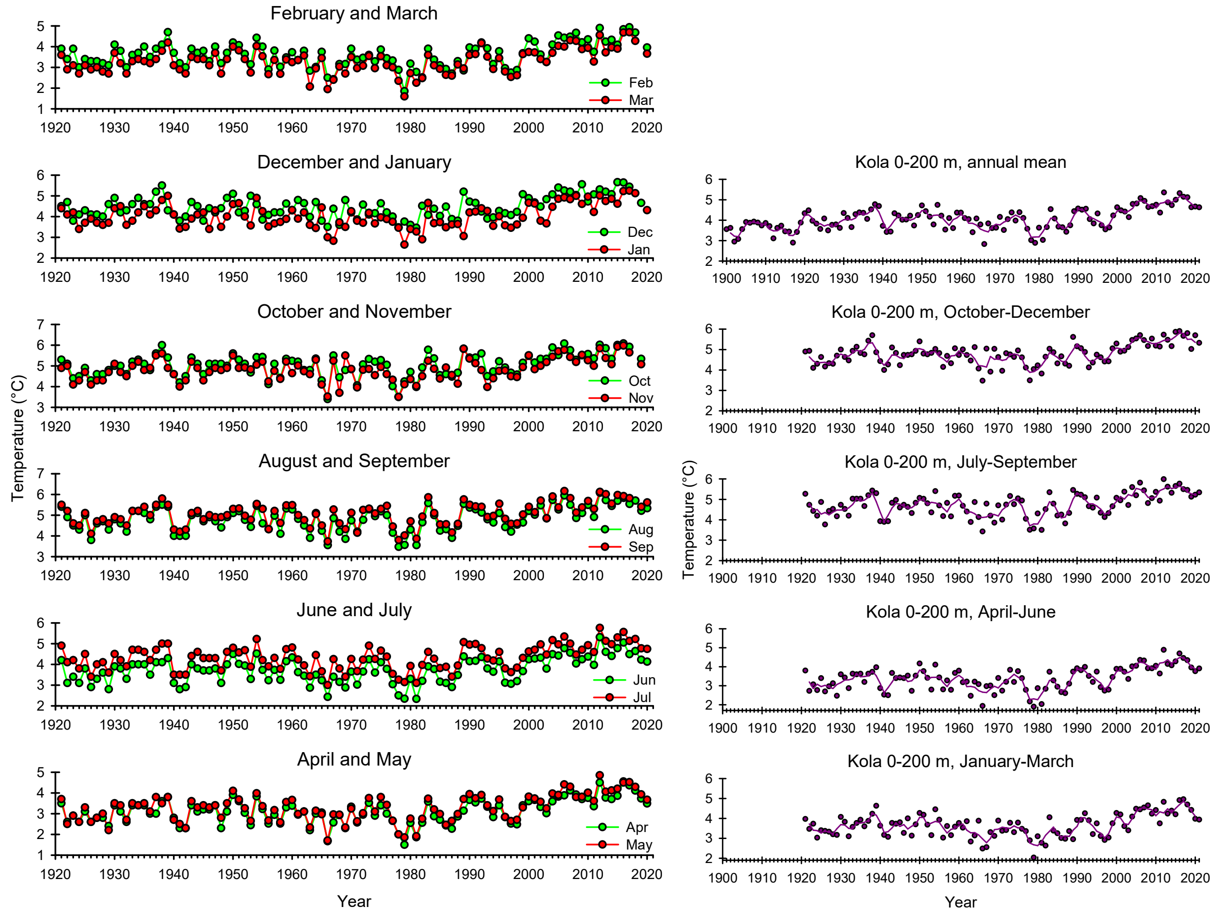

Figure 3. Long-term annual variations in the mean monthly sea temperatures (figure on the left), in four quarters of a year in the period 1920-2021 and in the mean annual values in the period 1900-2021 (figure on the right) in Kola section (st 3-7, 0-200 m) in Northern Kola Peninsula. Source; VNIRO (Russia).

Sea temperatures in the depth of 0-200 meters indicate each year clear differences between June and July but not so clear differences between April and May, August and September (Figure 3). Periodic fluctuations between each quarter of the year have simultaneous annual fluctuations.

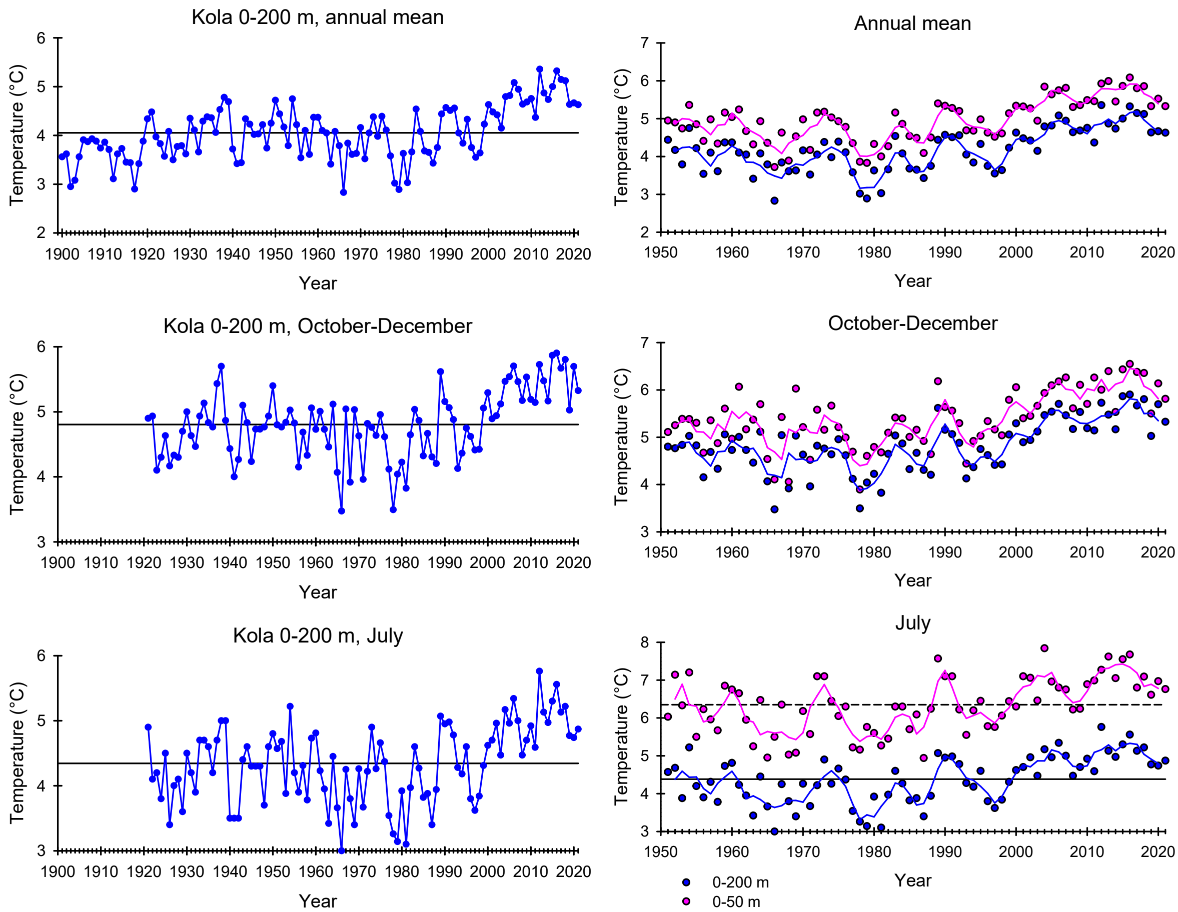

Figure 4. Long-term annual variations and means in the sea temperatures for July and for October-December in the years 1920-2021 and annual variations and mean in the years 1900-2021 in Kola section (st 3-7, 0-200 m) (figure on the left) and sea temperatures separated between 0-50 m and 0-200 m (figure on the right) in Northern Kola Peninsula. Source; VNIRO (Russia).

Mean annual sea temperature in the depth of 0-200 meters is appr. 4.3°C in July when salmon smolts are leaving their home rivers and enter into the coastal areas. When salmon is in the post smolt phase in October-December mean sea temperatures have been 4.9 °C (Figure 4).

Sea temperatures in Kola section are clearly higher in July in the surface layer (0-50 m) than in the deeper 0-200 m layer. Temperature conditions in this warmer upper layer might affect to the better survival of post smolts during their first months at sea. Also, later in the year in the period from October to December sea temperatures are different between the upper surface and deeper water layers. Sea temperatures are close the same in upper layer and in deeper layer in the first half of the year (Figure 5).

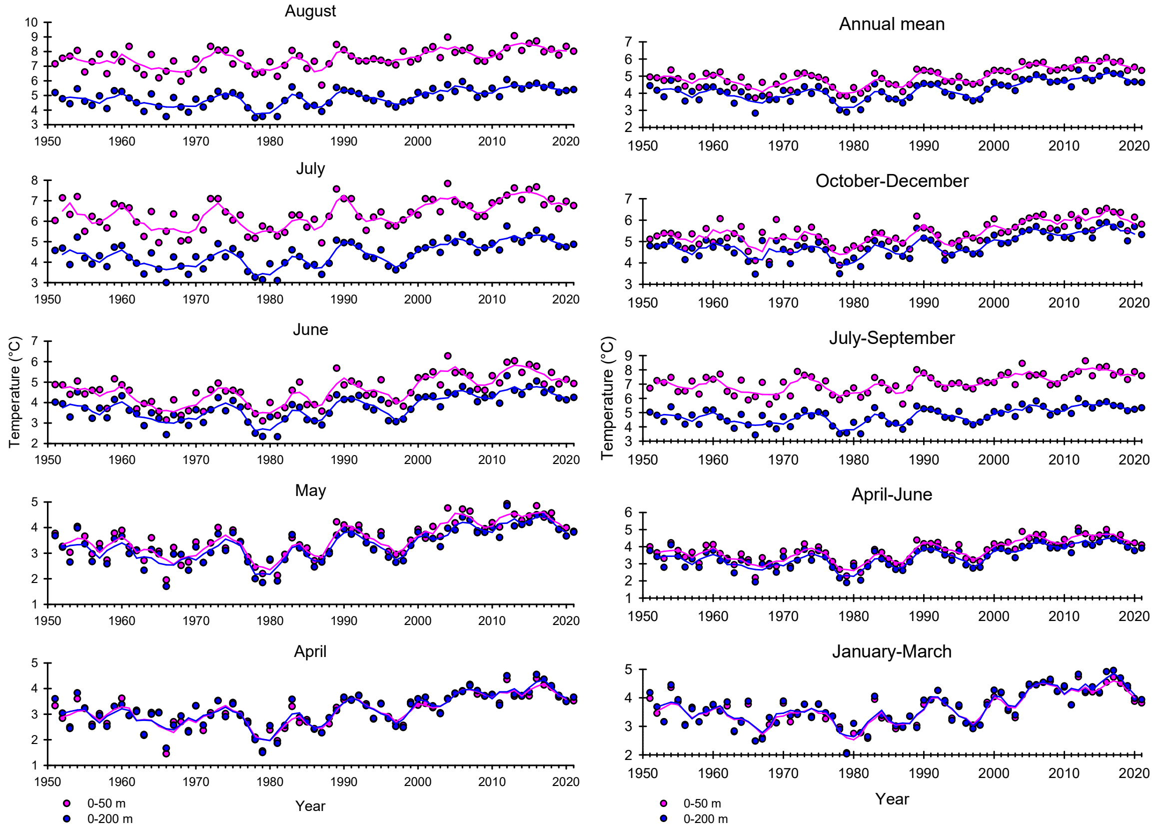

Figure 5. Long-term annual variations in the mean monthly (April-August) sea temperatures (figure on the left) and in four quarters of the year and annual means in the years 1950-2021 (figure on the right) in Kola section (st 3-7; 0-50 and 0-200 m) in Northern Kola Peninsula. Source; VNIRO (Russia).

Sea temperature deviations from the long-term annual mean temperatures in surface layer and in deeper layer are clearly indicating colder and warmer periods (Figure 6). Cold period phase has been in Barents Sea area early in the beginning of 1900´s continuing into 1930´s. After that quite long-lasting cold period there has been alternately more or less clear colder and warmer periods in the sea temperatures. Temperature measurements since the year 1950 have been more exact than measurements before that. Sea temperatures have been in 0-50 meters and 0-200 meters clearly warmer from the begin of 2000´s compared to the long-term annual mean temperatures and to the annual deviations in the long-term mean sea temperature. This warm period is exceptionally long compared to the durations of earlier warm and cold periods.

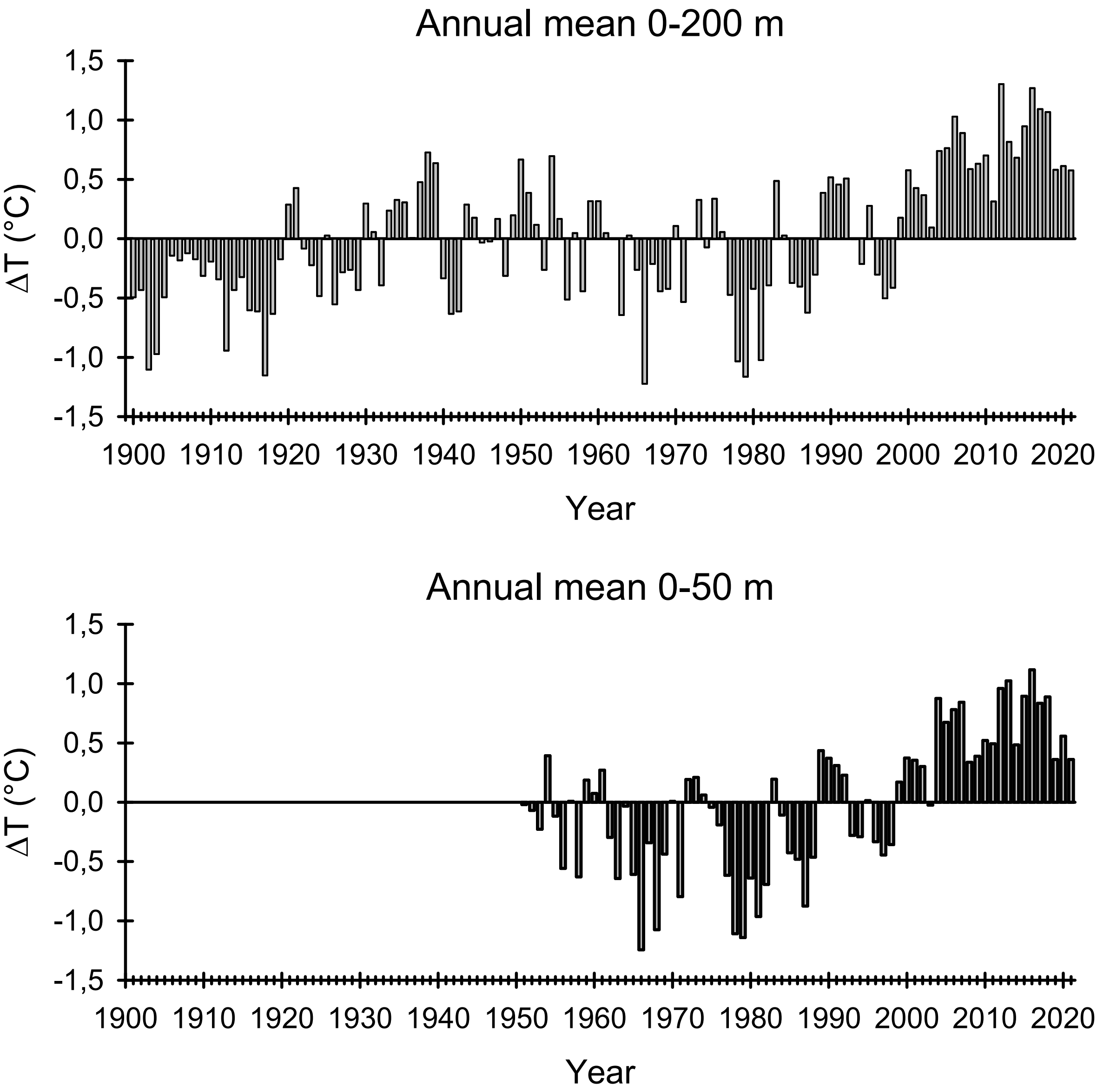

Figure 6. Deviations from the long-term mean annual sea temperatures in Kola section (Russia) (0-50 m, 0-200 m,). Source; VNIRO (Russia).

2. Sea temperatures in Kola section in Northern Kola Peninsula, 0-50 meters depth

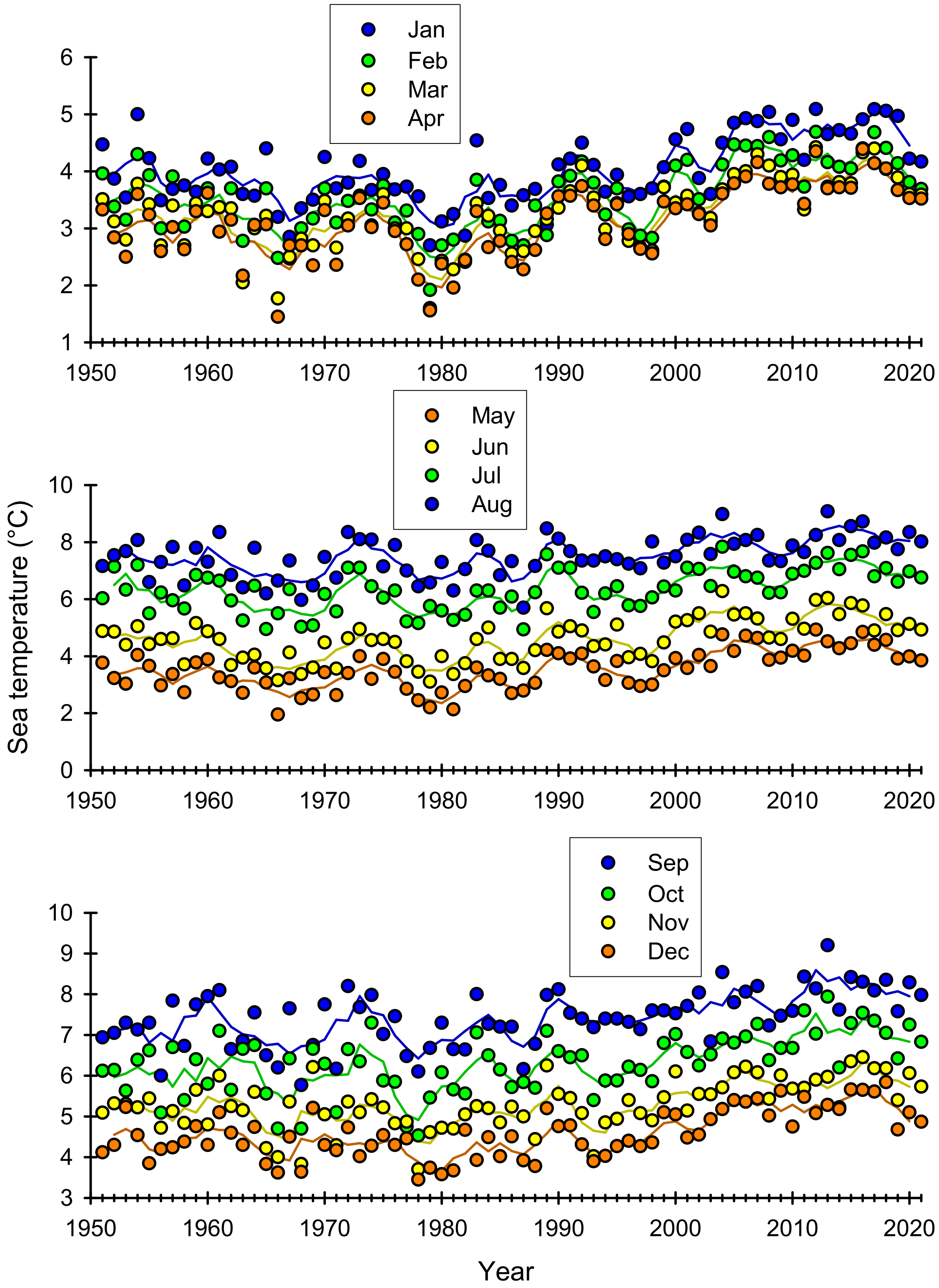

Figure 7. Long-term annual variations in the mean monthly sea temperatures from the year 1950 to the year 2021 in Kola section (st 3-7, 0-50 m) in Northern Kola Peninsula. Source; VNIRO (Russia).

Sea temperatures in the upper layer, surface area, are important for salmon. It is known that salmon smolts prefer the uppermost area after they have descended from rivers to saltwater. Adult salmon is also using uppermost layer when migrating towards its home river. Salmon fishermen have been using bend nets which are usually 7-15 meters in depth which indicates that adult salmon prefer swimming in warmer water during homing migrations. If sea temperatures continue to increase in future especially during those periods which are vital for the survival of salmon smolts, for the growth of maturing salmon and for the food items salmon is using then salmon may face increased sea mortality. Sea temperatures were in December in 1980´s appr. 3.5 °C and in the middle of 2010´s 5.5 °C (Figure 7). In May, when multi-seawinter salmon begins its homing migration along the northern coastal lines sea surface temperature was in early 1980´s appr. 2 °C but the temperature was 5 °C in the middle of 2010´s. This increase in temperatures is affecting to the earlier homeward migration of multi-seawinter salmon.

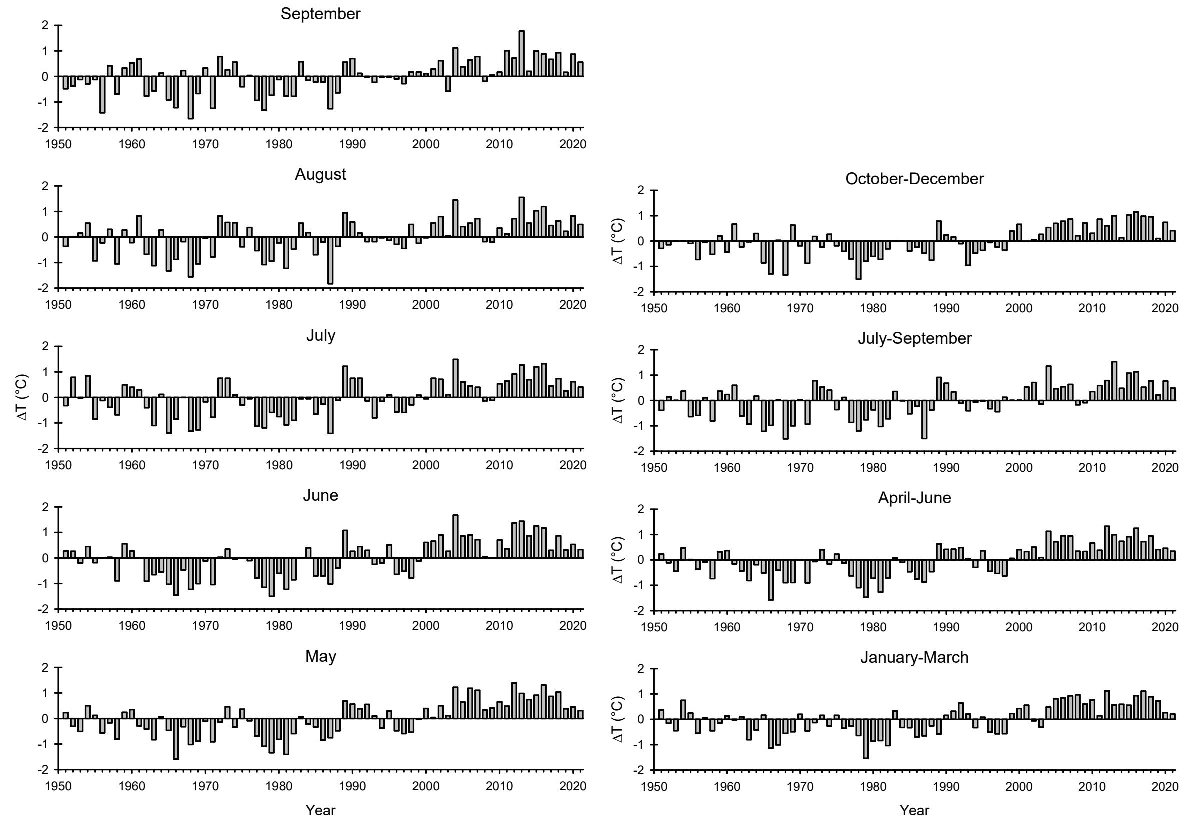

Figure 8. Annual deviations from the long-term mean monthly sea temperatures in Kola section (0-50 m) (Russia). Source; VNIRO (Russia).

Figure 8 is clearly indicating that there have been colder and warmer periods in sea temperatures. In all the summer months there has been very similar periods when monthly deviations from the long-term mean temperatures have lasted as many years. Temperature deviations from the long-term mean values between the quarters of the year are looking the same fluctuations. Since 2000´s deviations in the temperatures have been clearly positive compared to earlier decades.

Annual changes in sea temperatures in July are reflecting into the annual mean sea temperature values in Kola section (Figure 9).

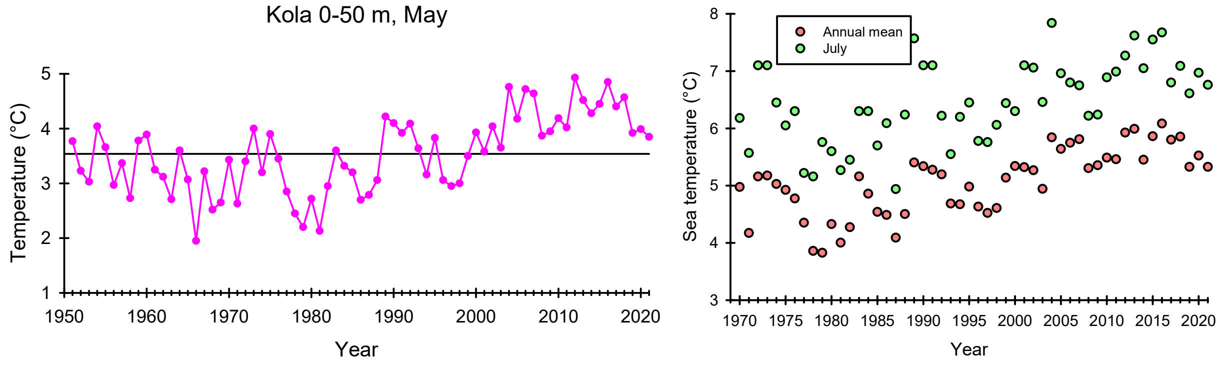

Figure 9. Annual variations in the sea temperatures in May with the long-term mean value in Kola section (figure on the left) and sea temperatures in July and long-term mean annual values in Kola section (section 0-50 m) (figure on the right). Source; VNIRO (Russia).

Figures 10 and 11 are illustrating monthly mean sea temperature changes during the years since 1920´s.

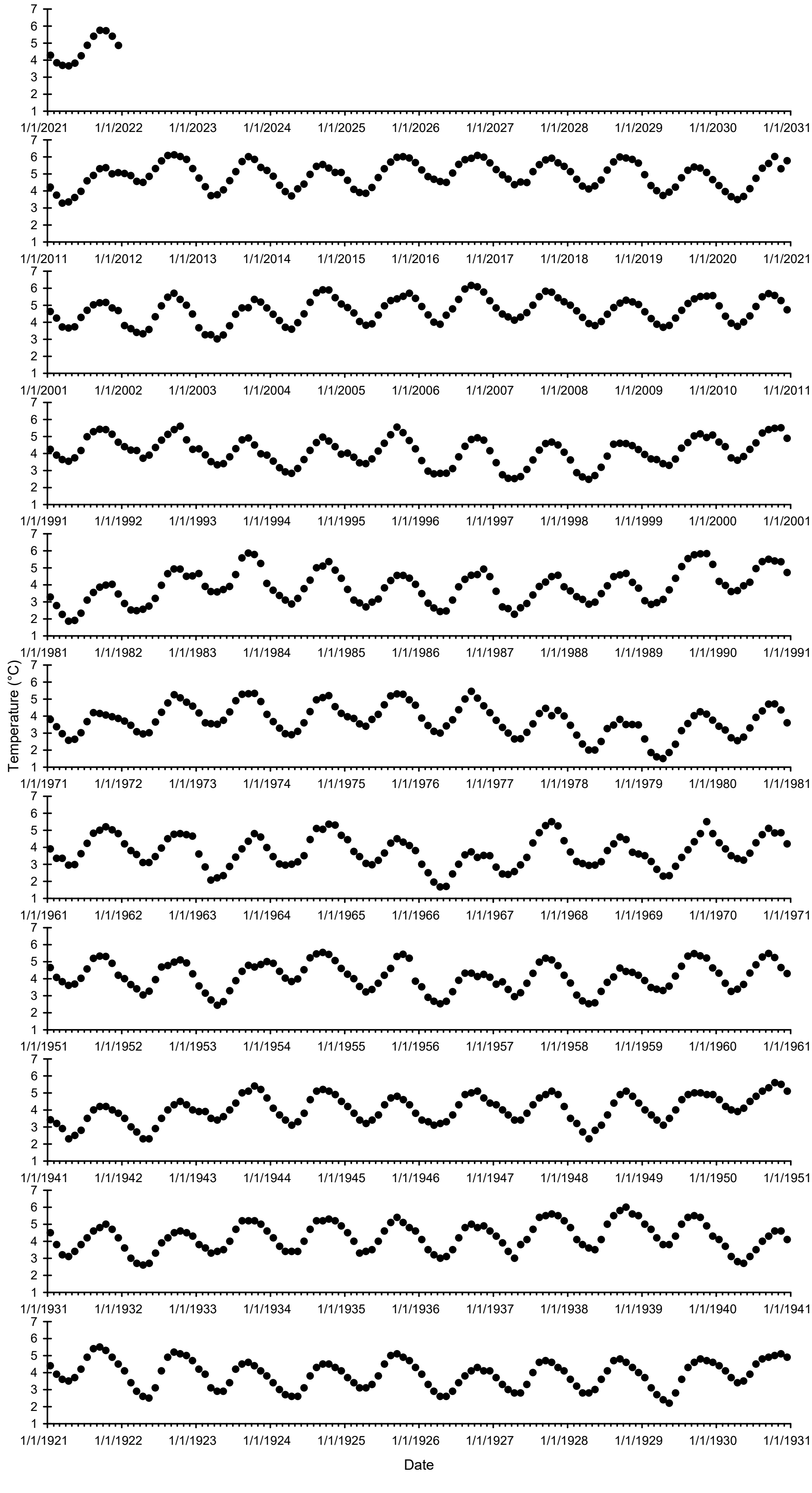

Figure 10. Mean monthly sea temperatures in Kola section (0-200 m). Source; VNIRO (Russia).

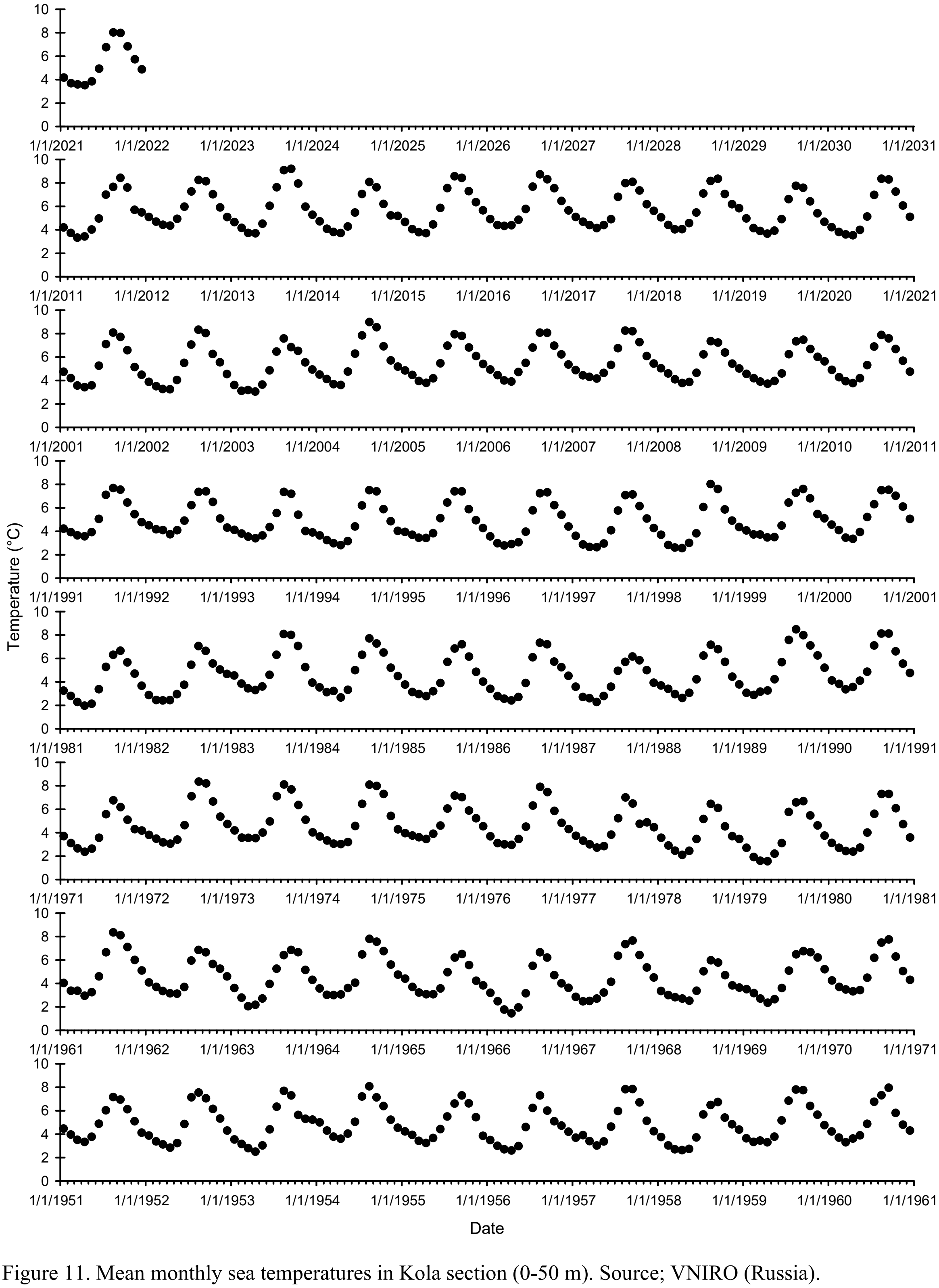

Figure 11. Mean monthly sea temperatures in Kola section (0-50 m). Source; VNIRO (Russia).

3. Sea temperatures in Varangerfjord

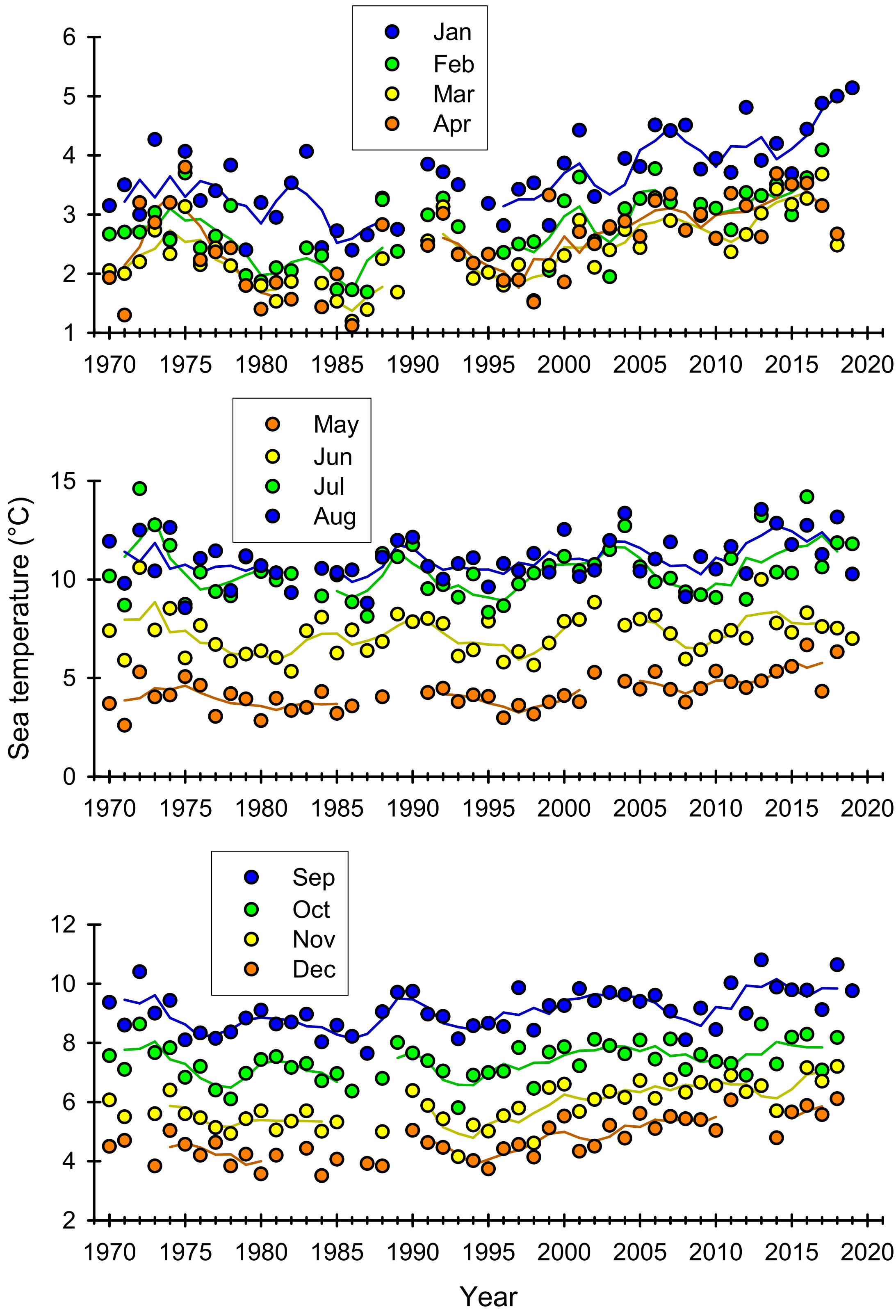

Figure 12. Long-term annual variations in the mean monthly sea temperatures from the year 1970 to the year 2021 in Varangerfjord. Source; IMR (Norway).

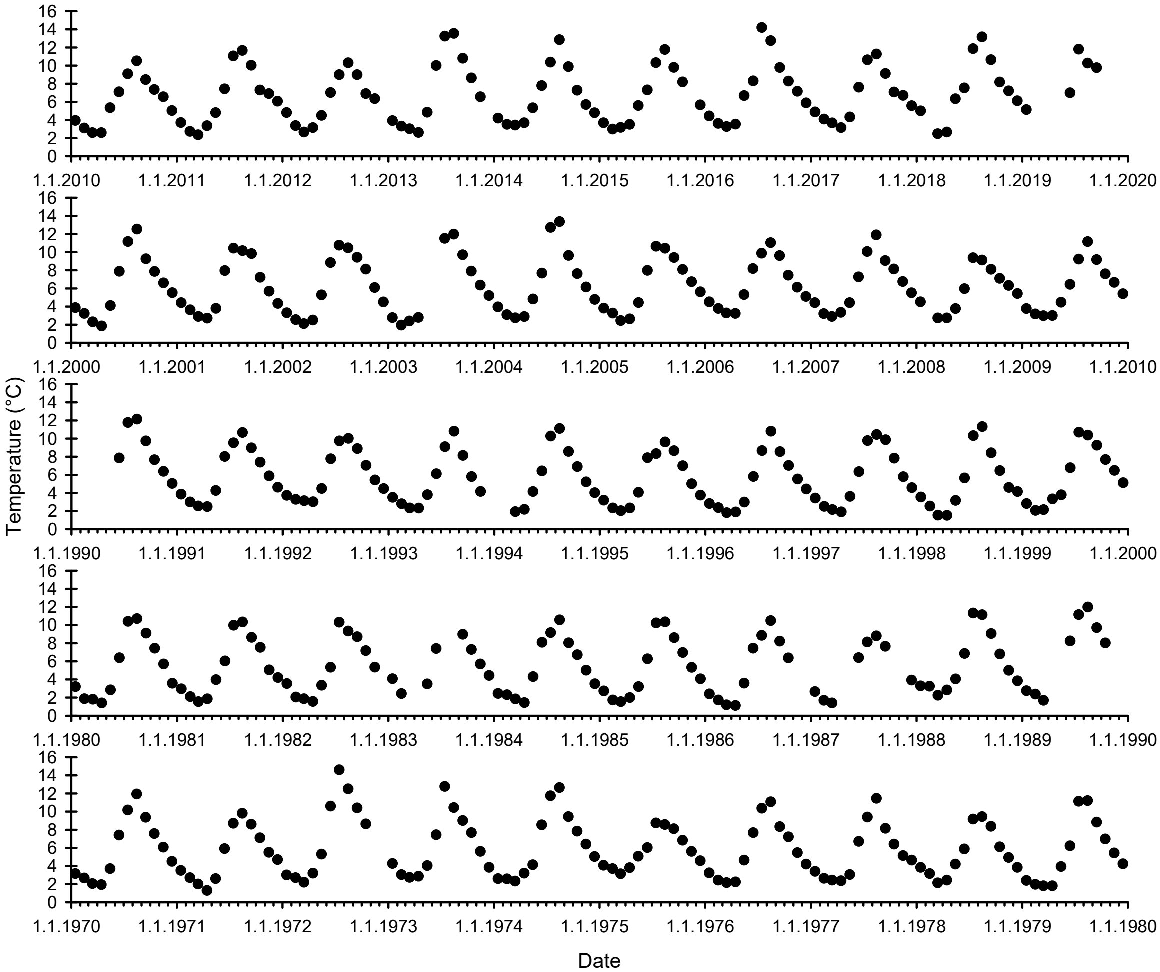

Figure 13. Sea temperatures in Varangerfjord from the year 1970 to the year 2019. Source; IMR (Norway).

4. Sea temperatures in Vardø

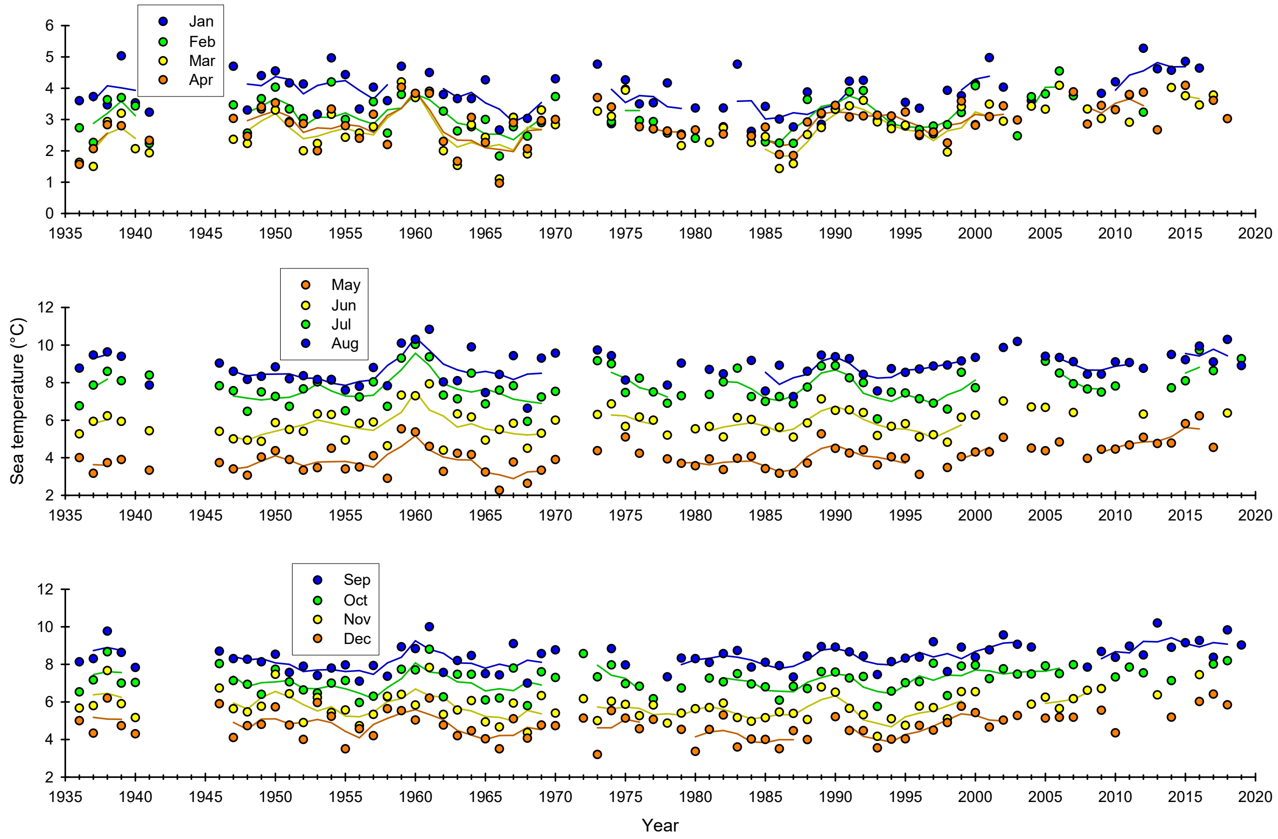

Figure 14. Long-term annual variations in the mean monthly sea temperatures from the year 1935 to the year 2019 in Vardø. Source; IMR (Norway).

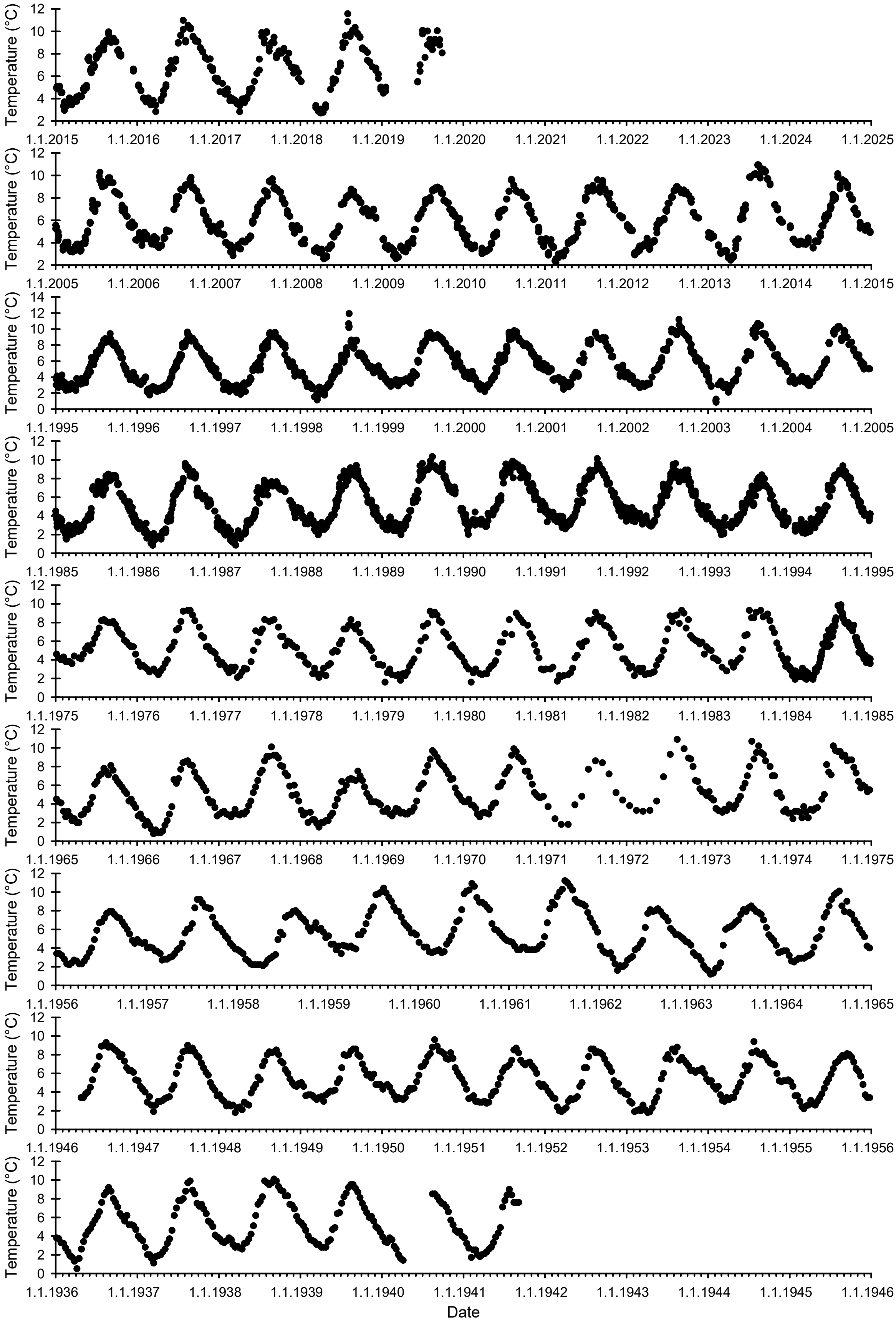

Figure 15. Sea temperatures in Vardø from the year 1936 to the year 2019. Source; IMR (Norway).

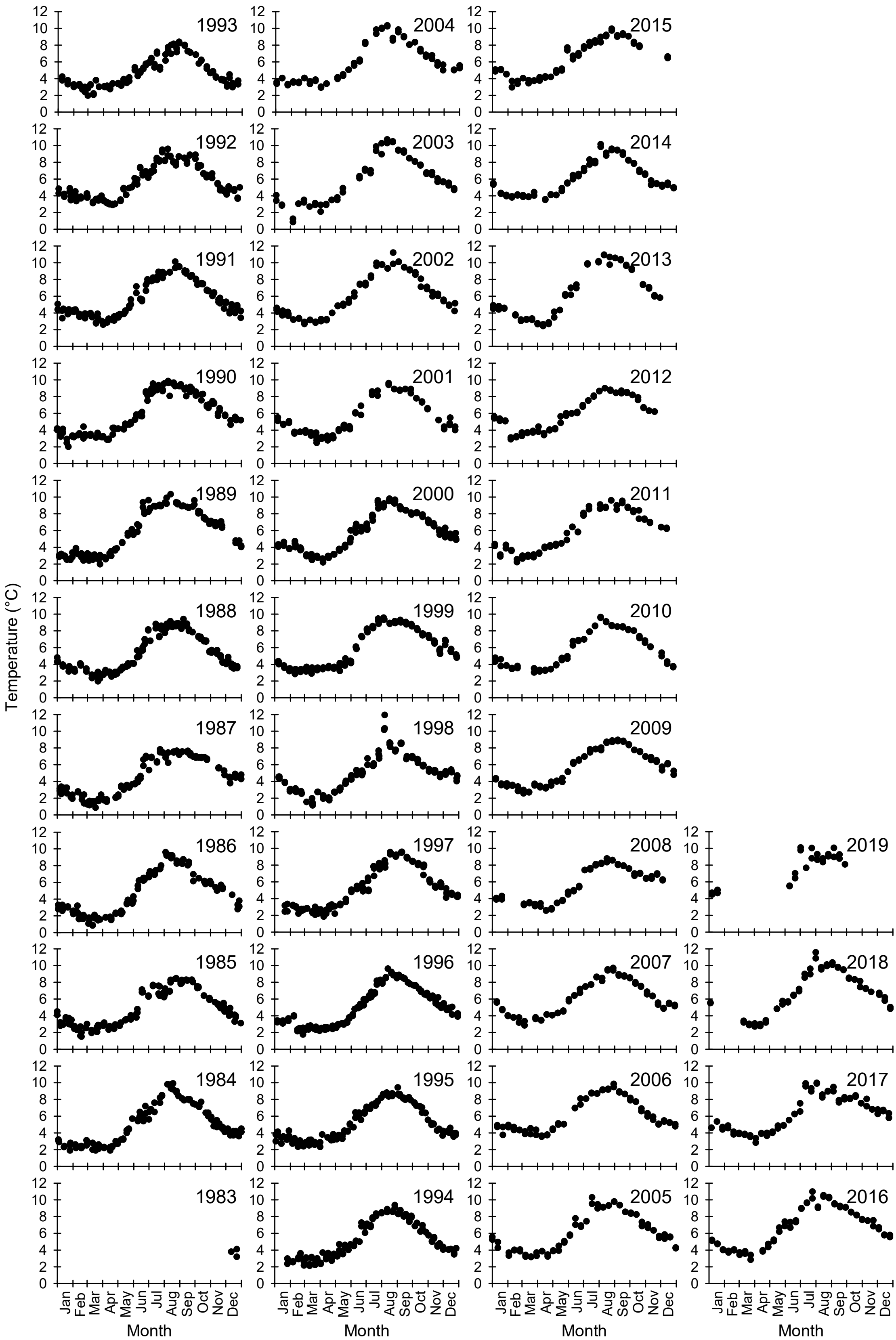

Figure 16. Sea temperatures in Vardø from the year 1983 to the year 2019. Source; IMR (Norway).

5. Sea temperatures in Tanafjord

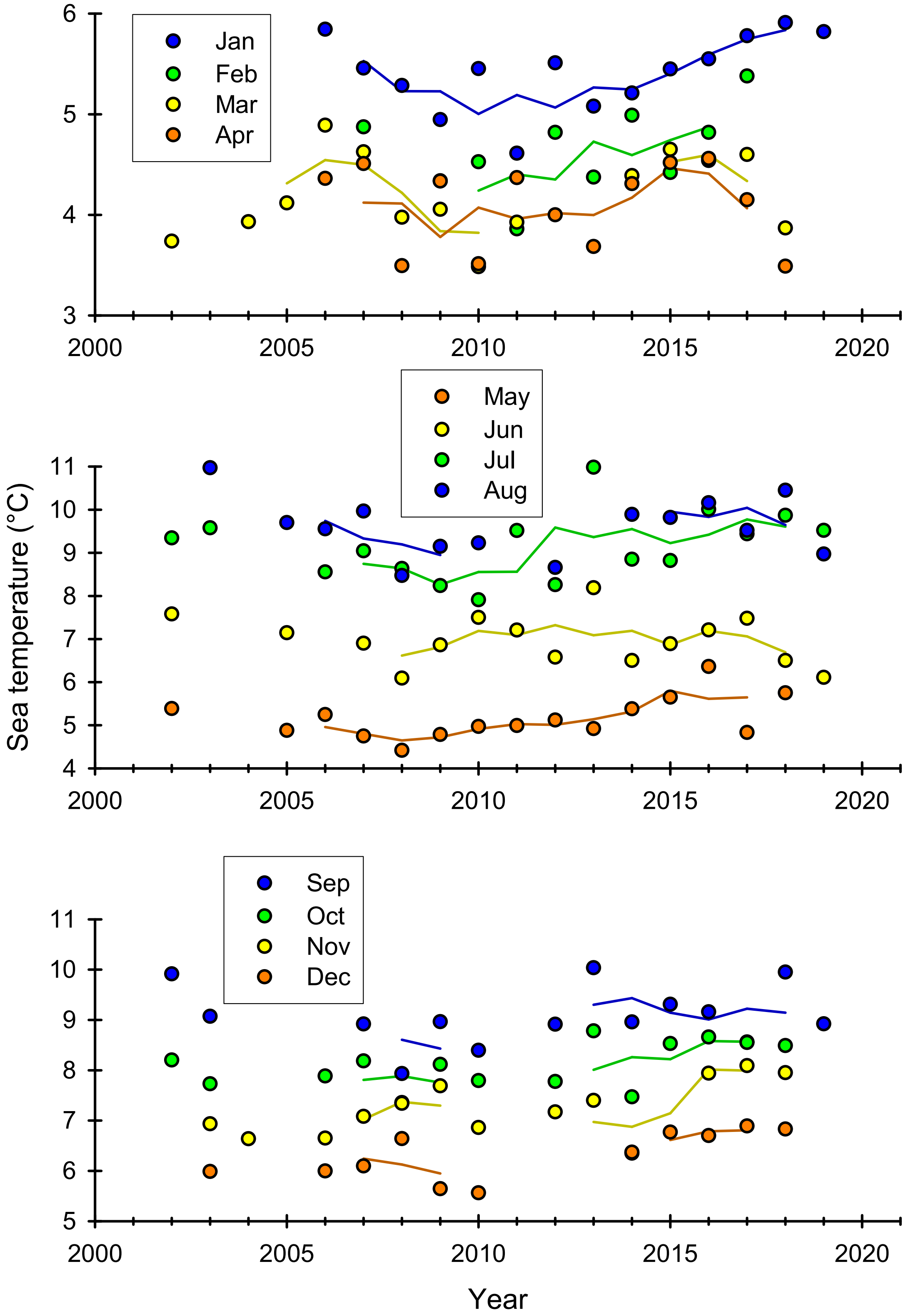

Figure 17. Long-term annual variations in the mean monthly sea temperatures from the year 2002 to the year 2019 in Tanafjord. Source; IMR (Norway).

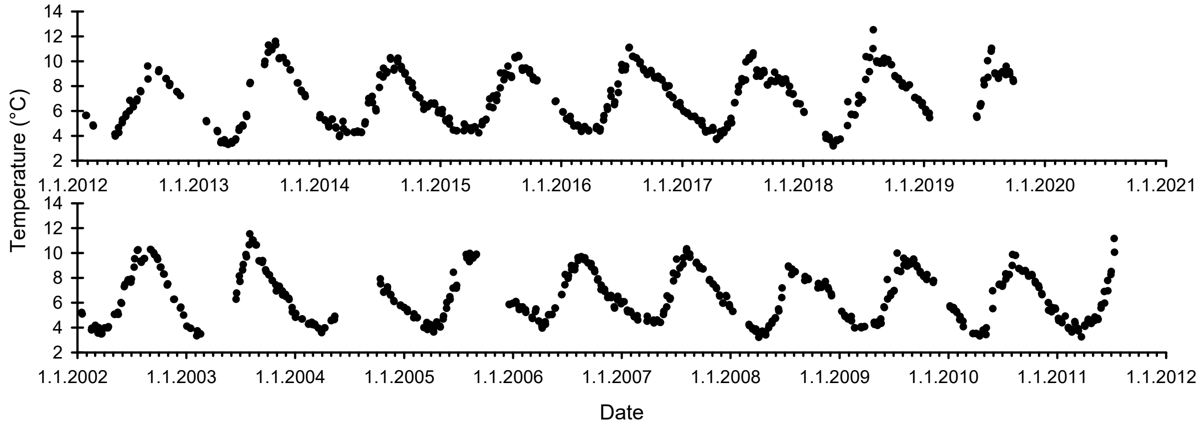

Figure 18. Sea temperatures in Tanafjord from the year 1982 to the year 2019. Source; IMR (Norway).

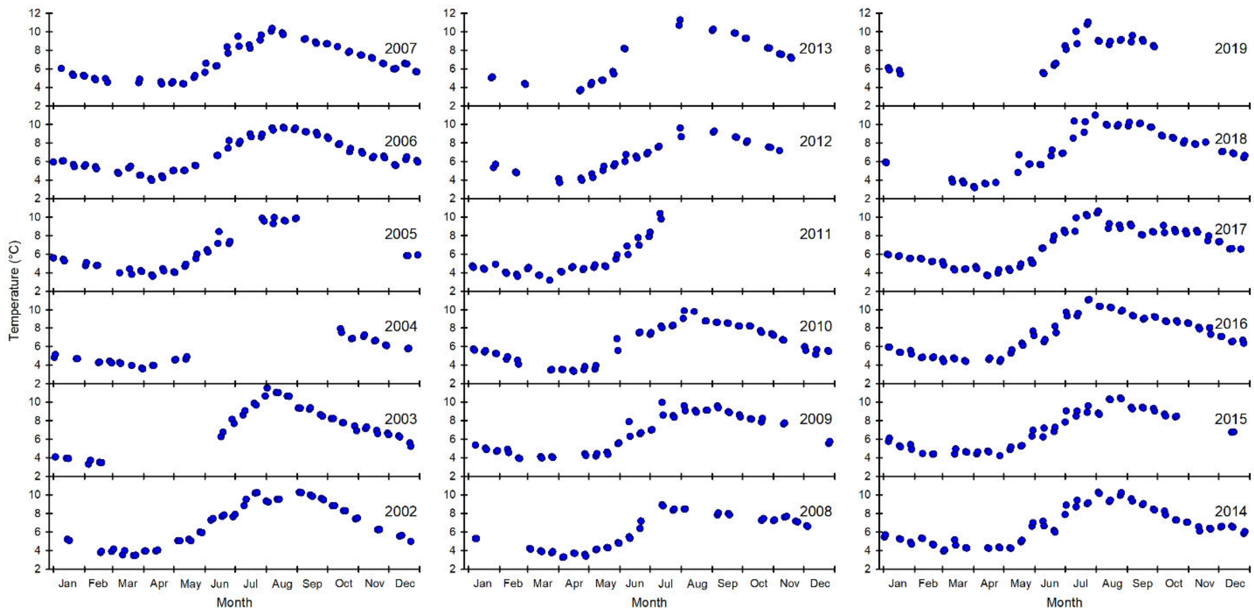

Figure 19. Sea temperatures in Tanafjord from the year 1982 to the year 2019. Source; IMR (Norway).

6. Sea temperatures in Laksefjord

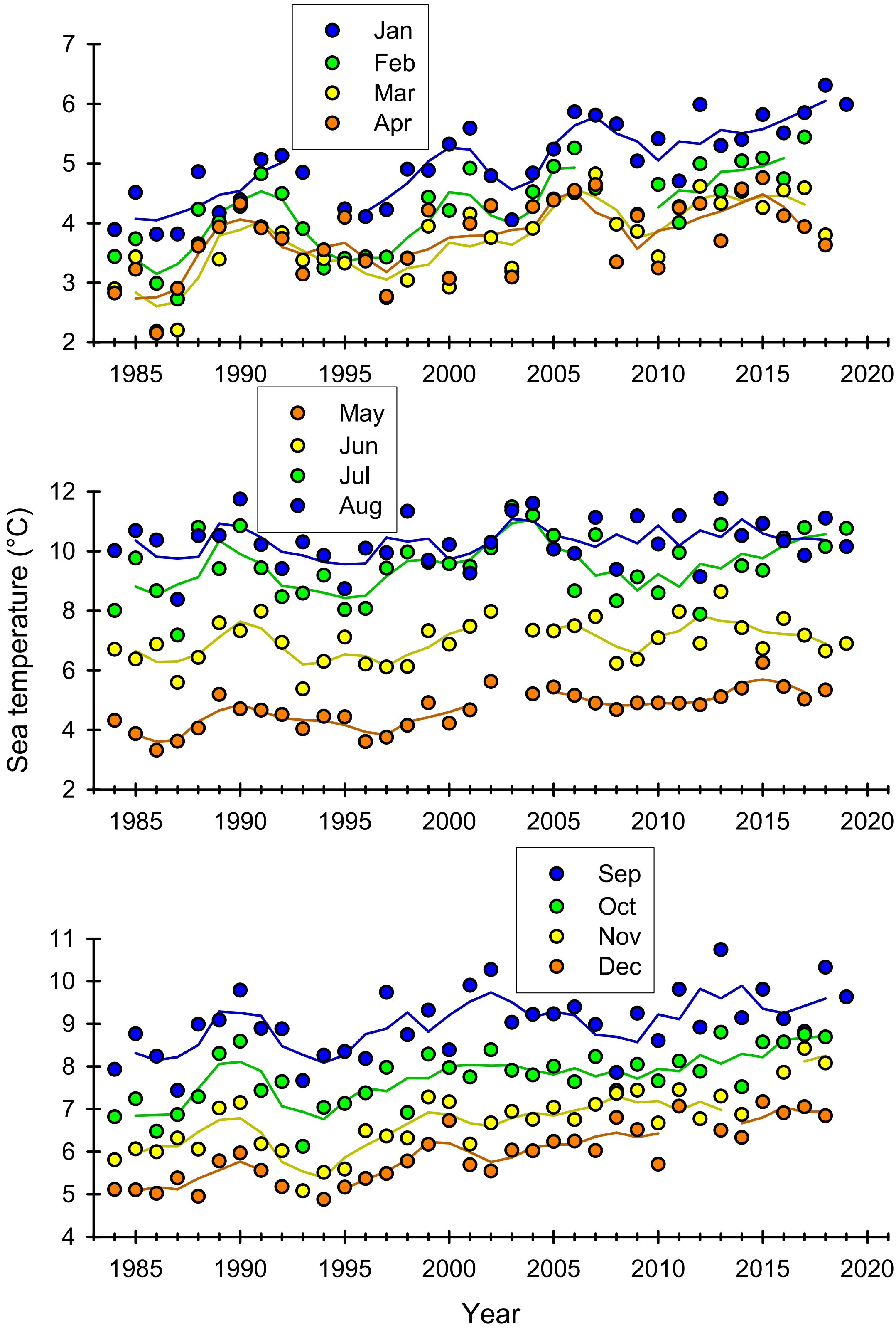

Figure 20. Long-term annual variations in the mean monthly sea temperatures from the year 1984 to the year 2019 in Laksefjord. Source; IMR (Norway).

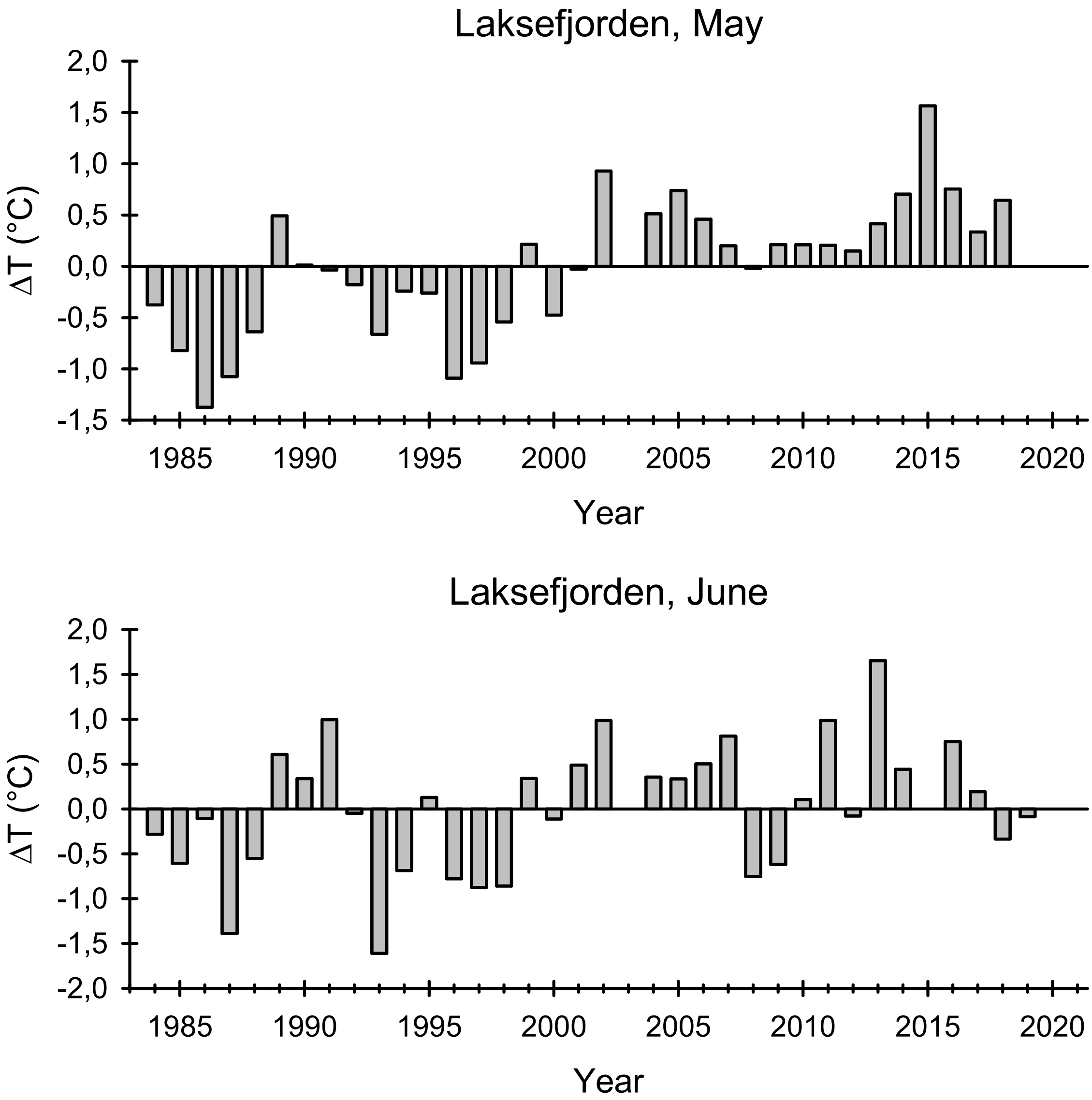

Figure 21. Annual deviations from the long-term mean monthly sea temperatures for May and June in Laksefjord. Source; IMR (Norway).

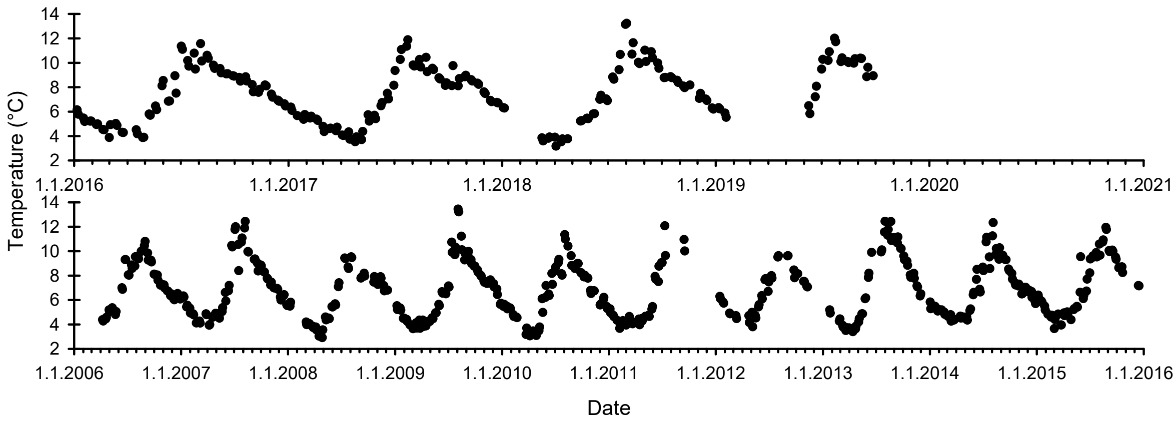

Figure 22. Sea temperatures in Laksefjord from the year 2006 to the year 2019. Source; IMR (Norway).

7. Sea temperatures in Ingøy

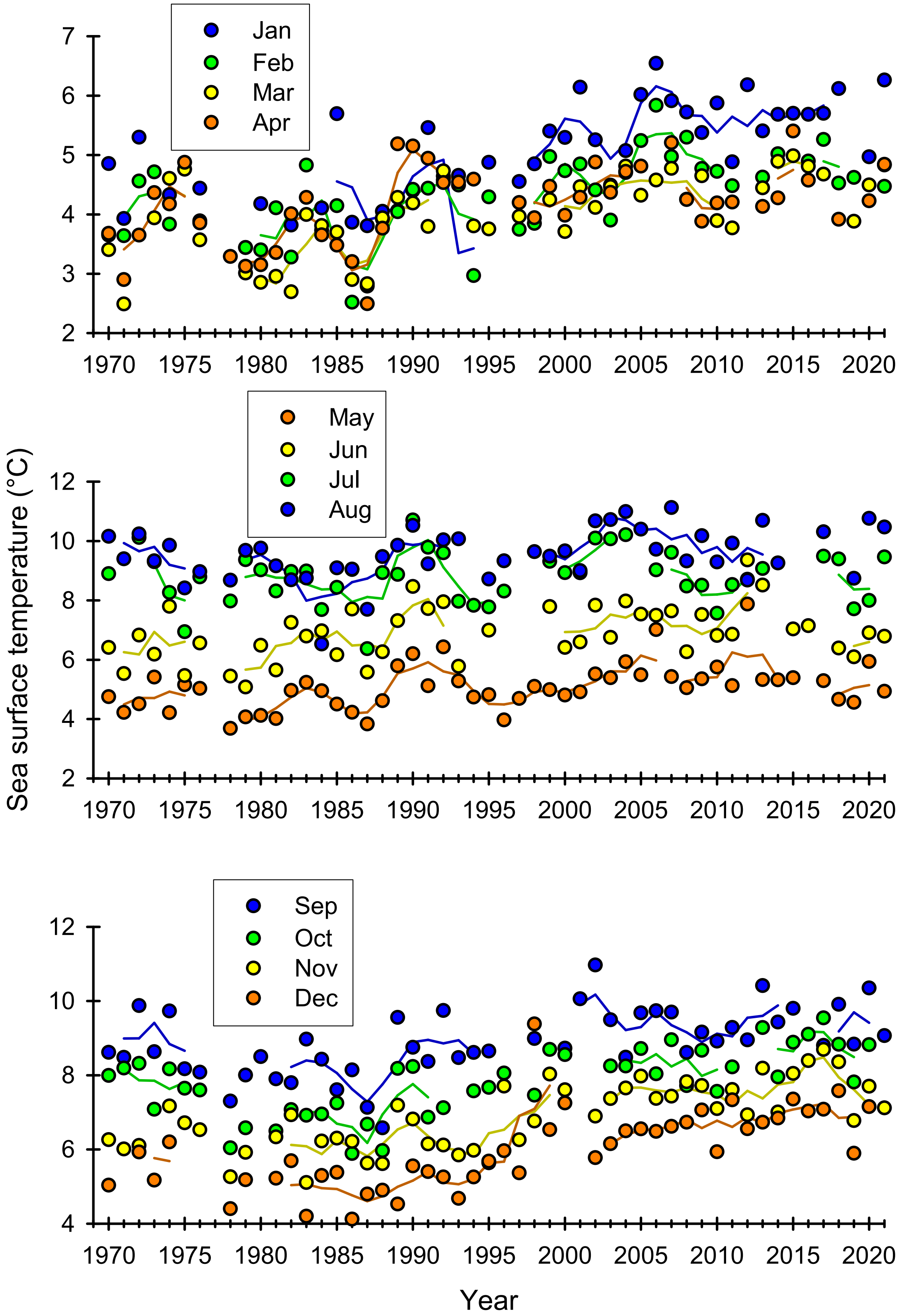

Figure 23. Long-term annual variations in the mean monthly sea temperatures from the year 1970 to the year 2021 in Ingøy. Source; IMR (Norway).

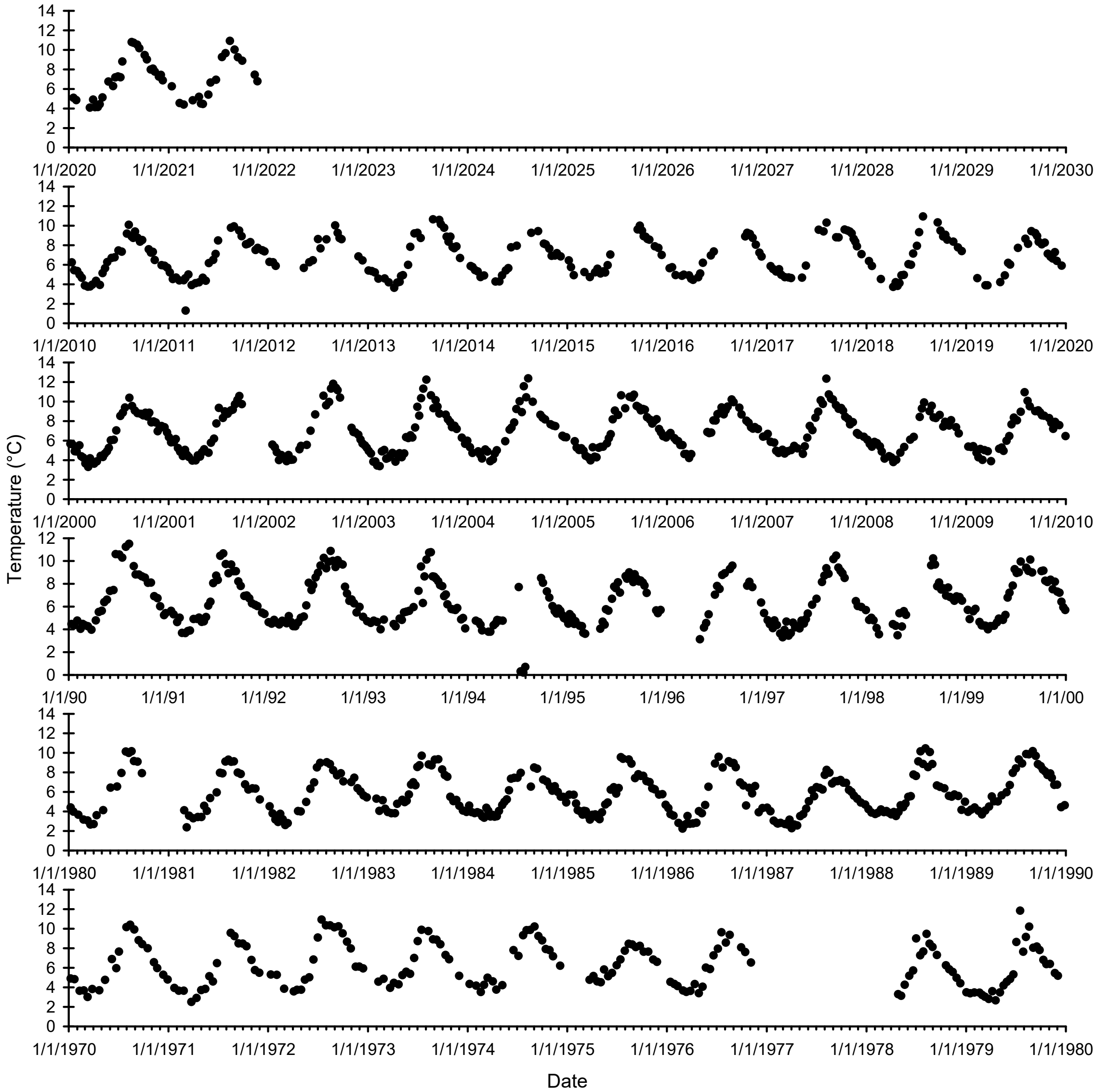

Figure 24. Sea temperatures in Ingøy from the year 1970 to the year 2021. Source; IMR (Norway).

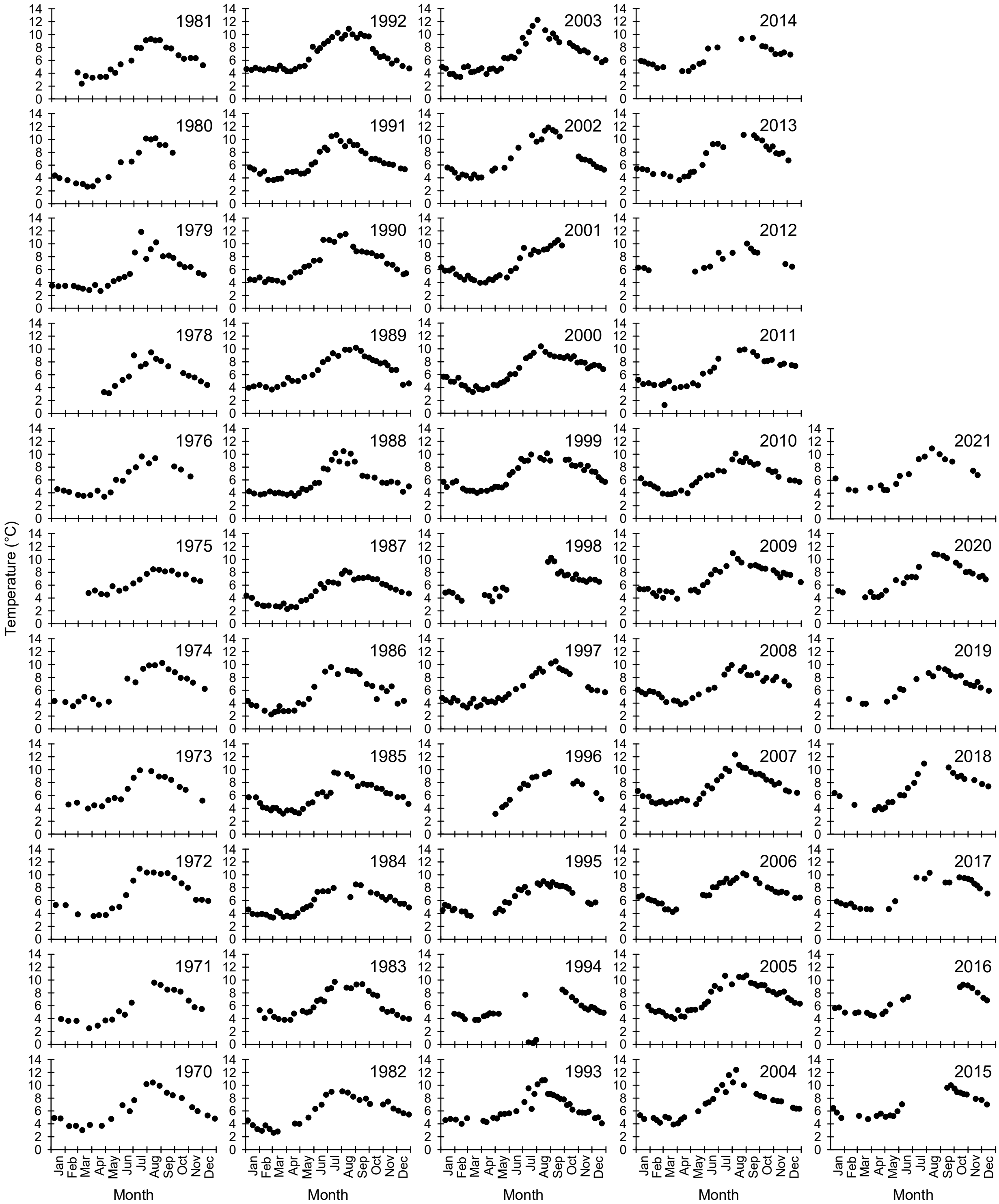

Figure 25. Sea temperatures in Ingøy from the year 1970 to the year 2021. Source; IMR (Norway).

8. Sea temperatures in Loppa

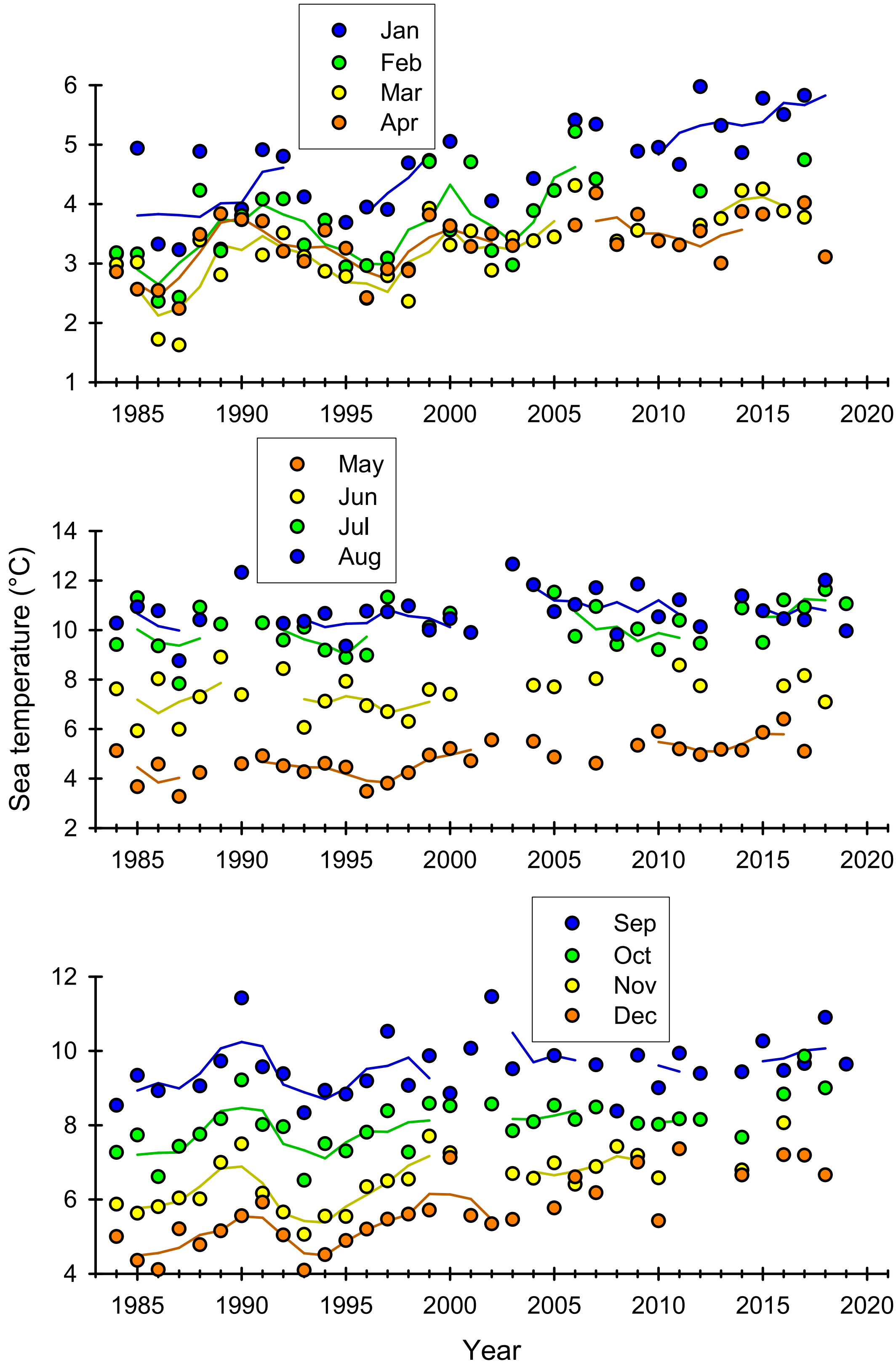

Figure 26. Long-term annual variations in the mean monthly sea temperatures from the year 1984 to the year 2019 in Loppa. Source; IMR (Norway).

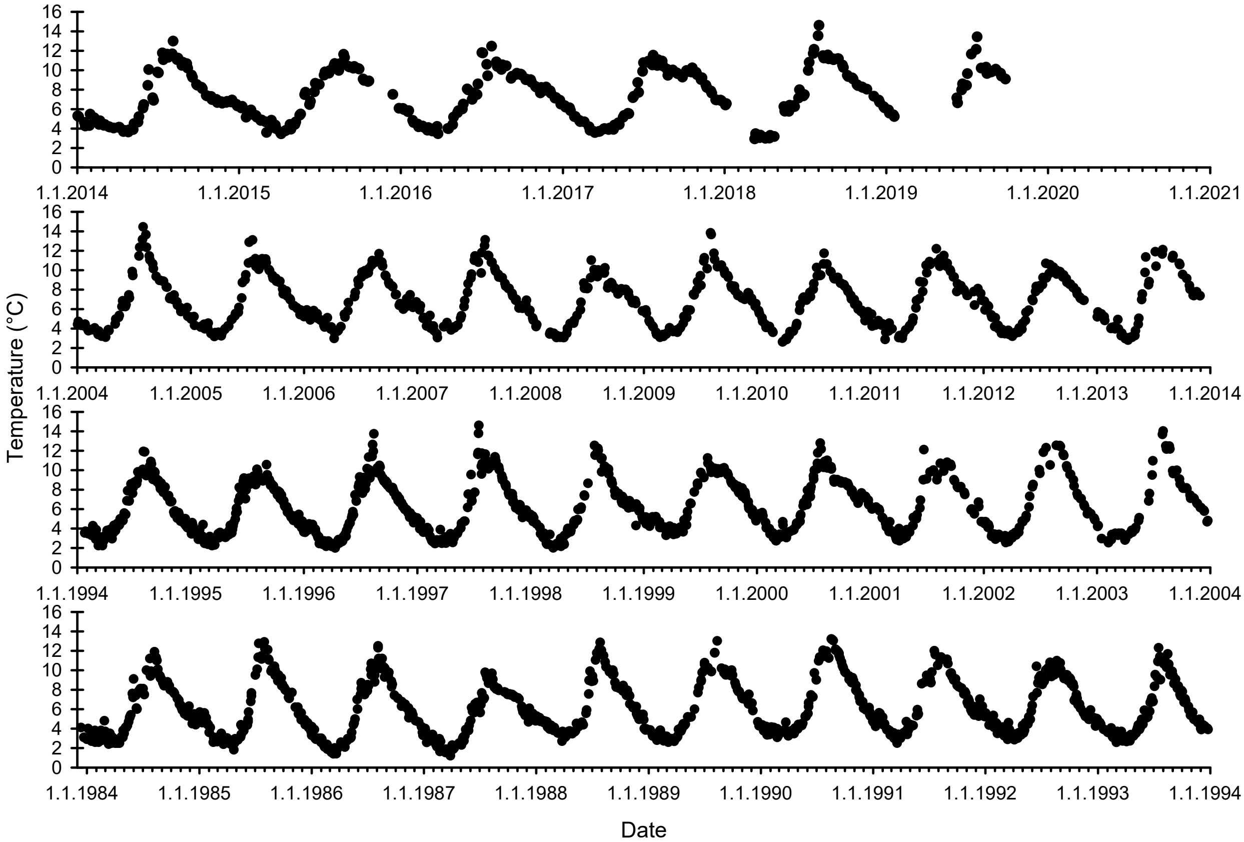

Figure 27. Sea temperatures in Loppa from the year 1984 to the year 2019. Source; IMR (Norway)

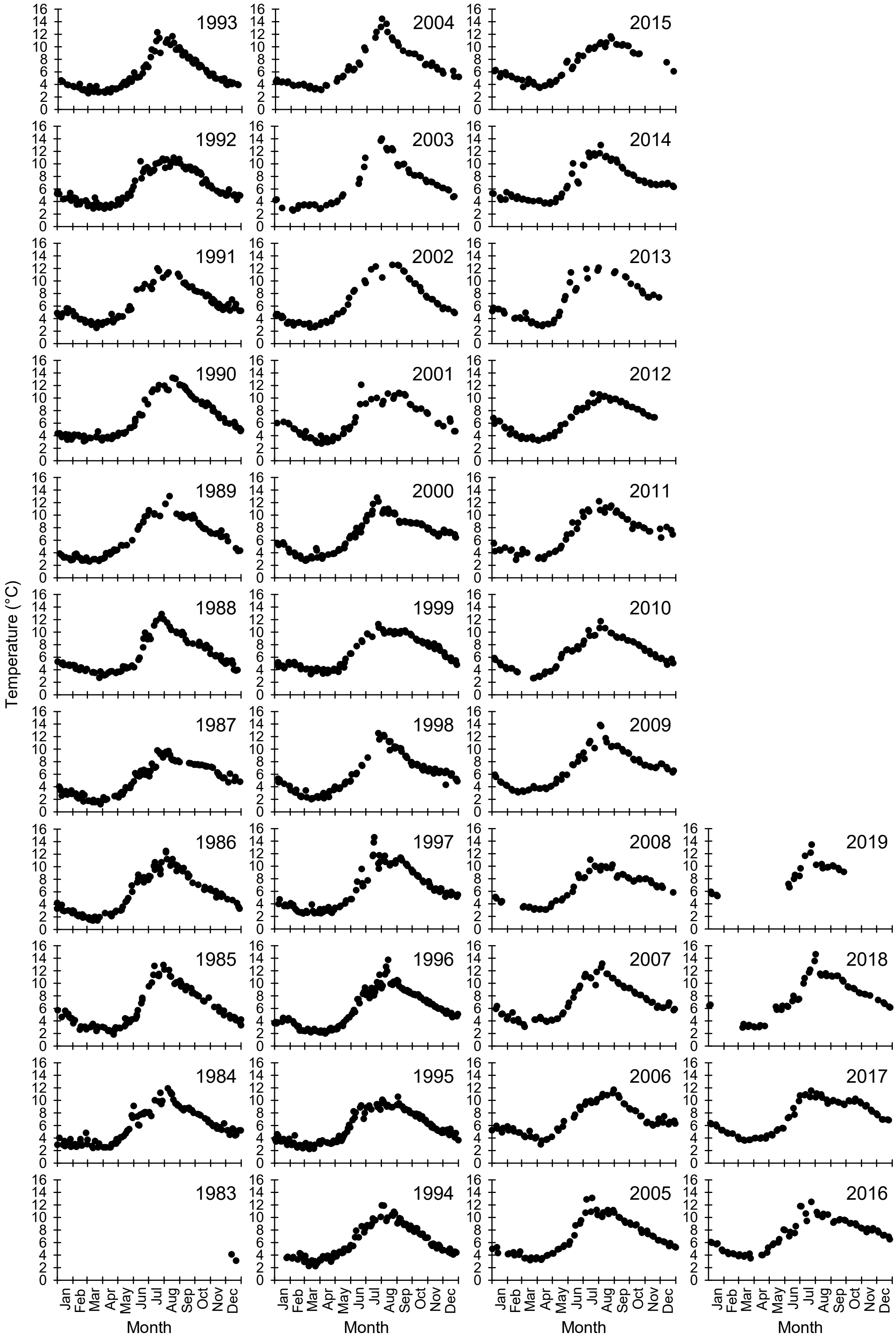

Figure 28. Sea temperatures in Loppa from the year 1983 to the year 2019. Source; IMR (Norway)

9. Trends and simultaneous variations in the sea temperatures between geographical areas

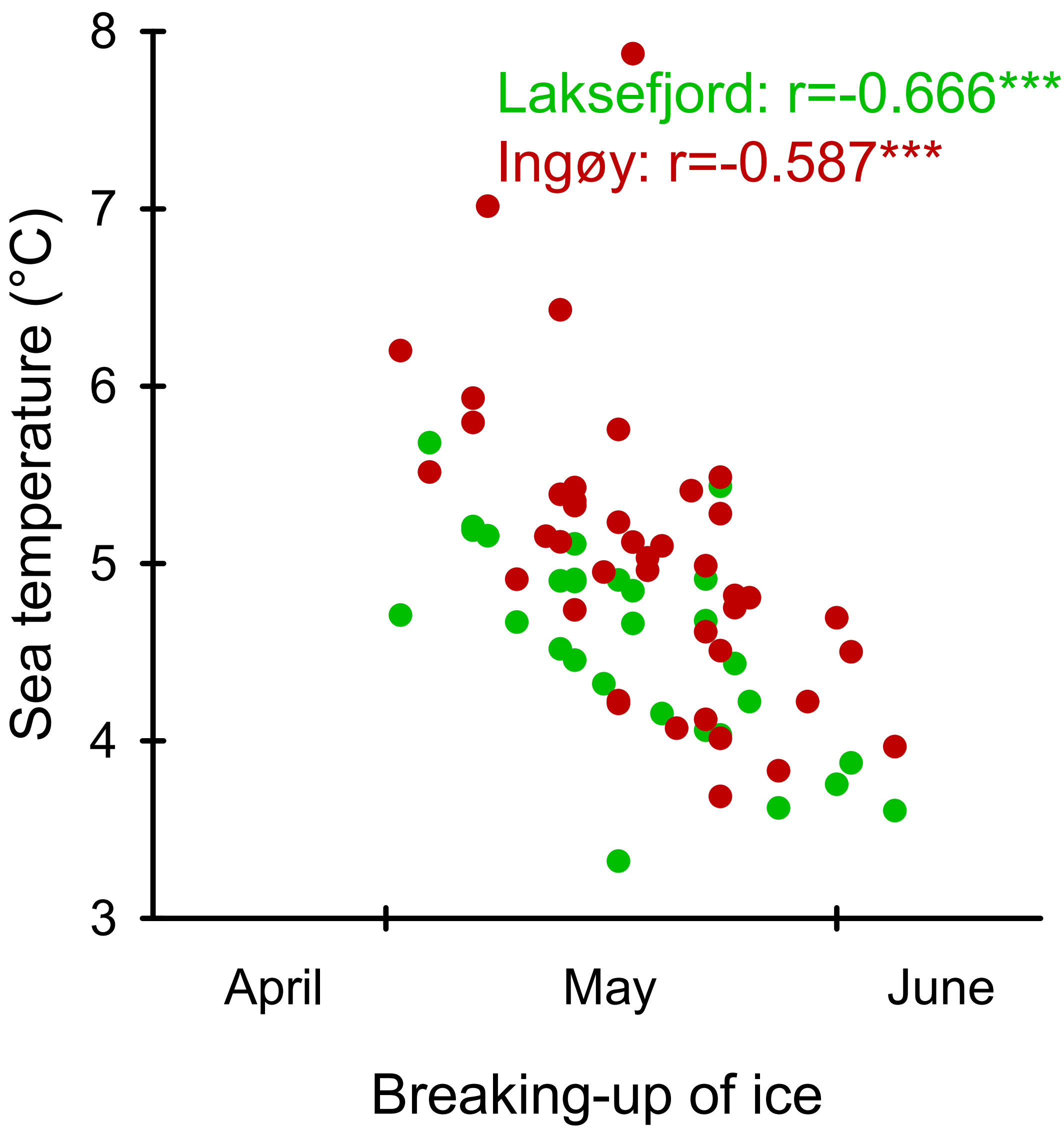

Figure 29. Mean long-term sea temperatures in May month in Laksefjord and in Ingøy. Source; IMR (Norway).

Sea temperature and its annual fluctuation is the most important factor affecting the primary production at sea and thereafter reflecting into the fish production. Figures like 1, 3, 7, 20 and 23 indicates clear long-term fluctuations in the sea surface temperatures within the large northern coastal areas in Norway and in Russia in each month of the year. These monthly fluctuations are taking place simultaneously between fjords and coastal areas. Coastal sea surface temperatures are reflecting those changes in air temperatures which are warming up sea surface waters in southern Atlantic areas. The Atlantic Golf-stream and its side streams transports during some periods of years warmer and in other periods of year colder waters into the Barents Sea. It is noteworthy that sea surface temperatures are getting warmer or colder gradually along the years. This step-by step change in sea temperature can then cause gradual changes in primary production, crustacean production and in fish production.

It is well known that salmon stocks have considerable annual variations reflecting into the catch variations in coastal and river fisheries. Sea surface temperature at the time when smolts descends from rivers to the sea is an important and effective factor in regulating the size of salmon stocks. These smolts, or so-called post smolts, starts their ocean feeding and growing period in the northern areas shortly after they have migrated from rivers to sea. This is a quite short time period (smolt window) lasting from middle of June to the middle of July. Post smolts are vulnerable to high predation during first months at sea but, optimal sea water temperatures with good nourishment affects the size of salmon stocks.

Climate (air temperatures) in wider but also in local geographical area together with sea surface temperature in coastal areas are influencing the ice break-up dates, like it does in the River Tana. Figure 29 clearly indicates that there has been synchrony between the days of ice break-up in the River Tana and the mean sea surface temperatures in May in Laksefjord and in Ingøy in Northern Norway. This clearly indicates that there are interactions between global increase in the climate (air temperatures) that has increased the coastal sea surface temperatures in the coastal areas in Barents region and these environmental factors together have affected into the early ice break-up dates in recent years.

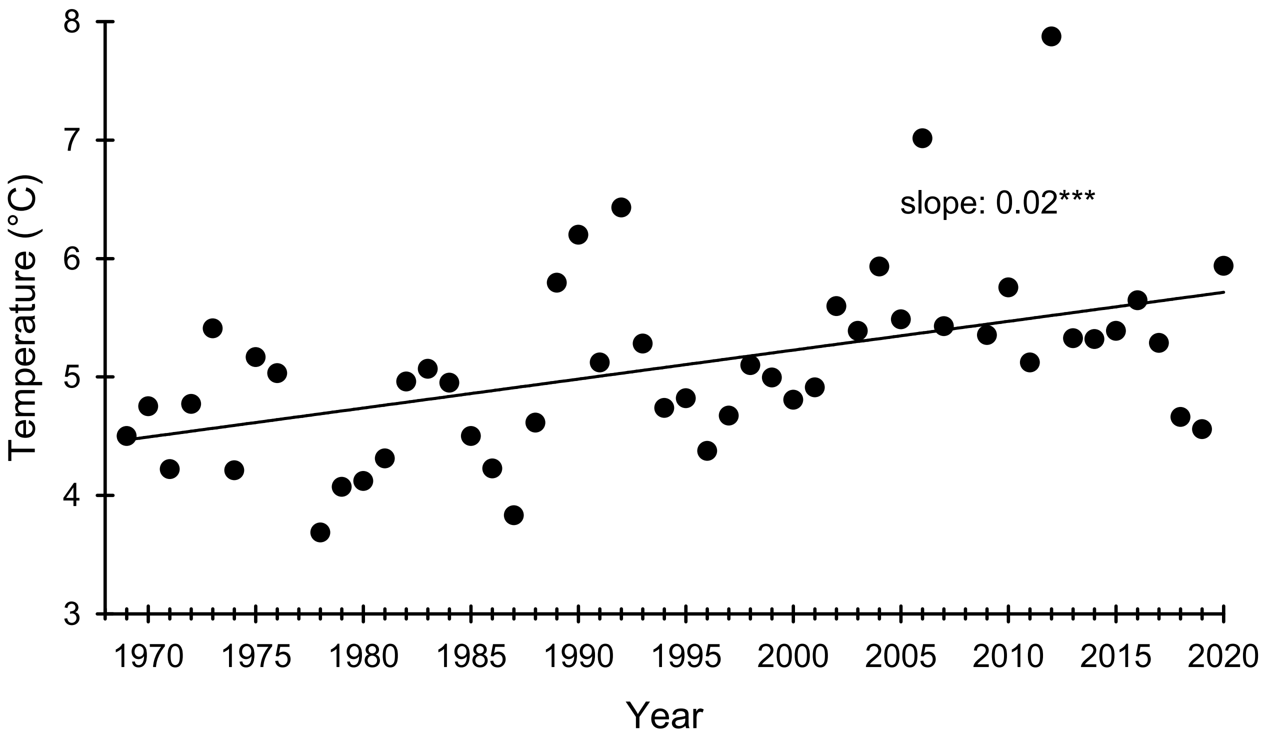

Figure 30. Increasing long-term trend in the mean sea temperature for May month in Ingøy. Source; IMR (Norway)

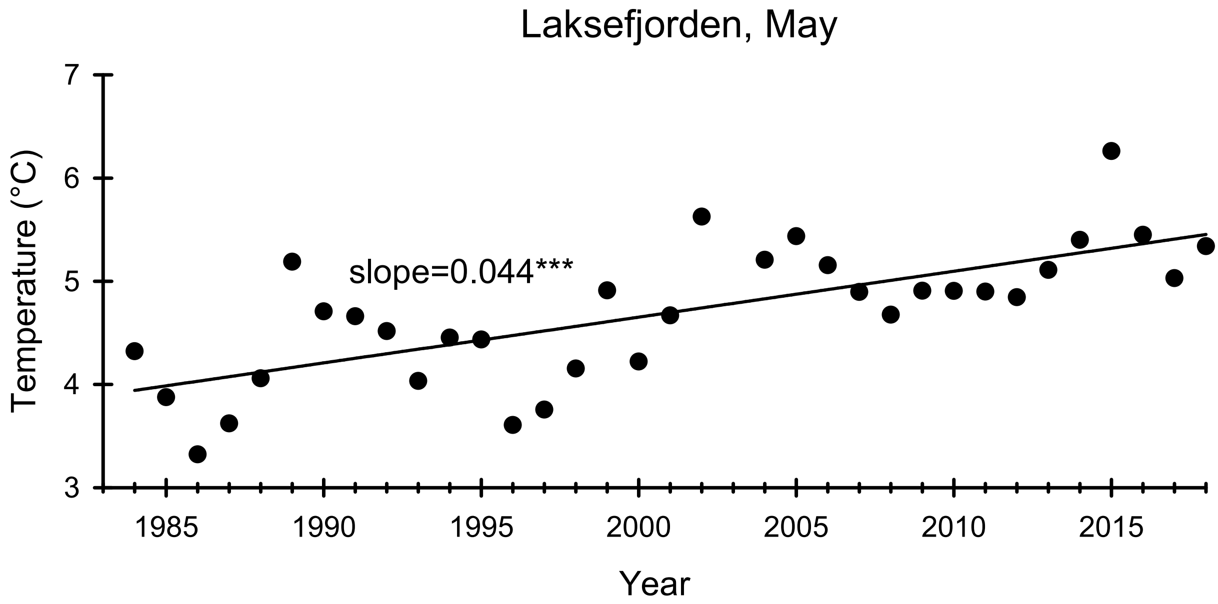

Figure 31. Increasing long-term trend in the mean sea temperature for May month in Laksefjorden. Source; IMR (Norway).

Figures 30 and 31 are clearly indicating that sea temperatures have increased in May when large salmon usually has started to migrate close to the outer coastlines and fjords in Finnmark area. The same long-term increase in the sea surface temperatures in autumn (mean temperatures in October-December period) can be observed from figures 32 and 33.

Sea surface temperatures in outer coastal areas are in general lowest in Kola section from May to September when compared to temperatures in Laksefjorden, Ingøy and Vardø (Figure 34, 35). Sea surface temperatures in Varangerfjord, however, are the coldest in the period from January to April when comparing to temperatures in Laksefjorden, Ingøy and Vardø (Figure 35).

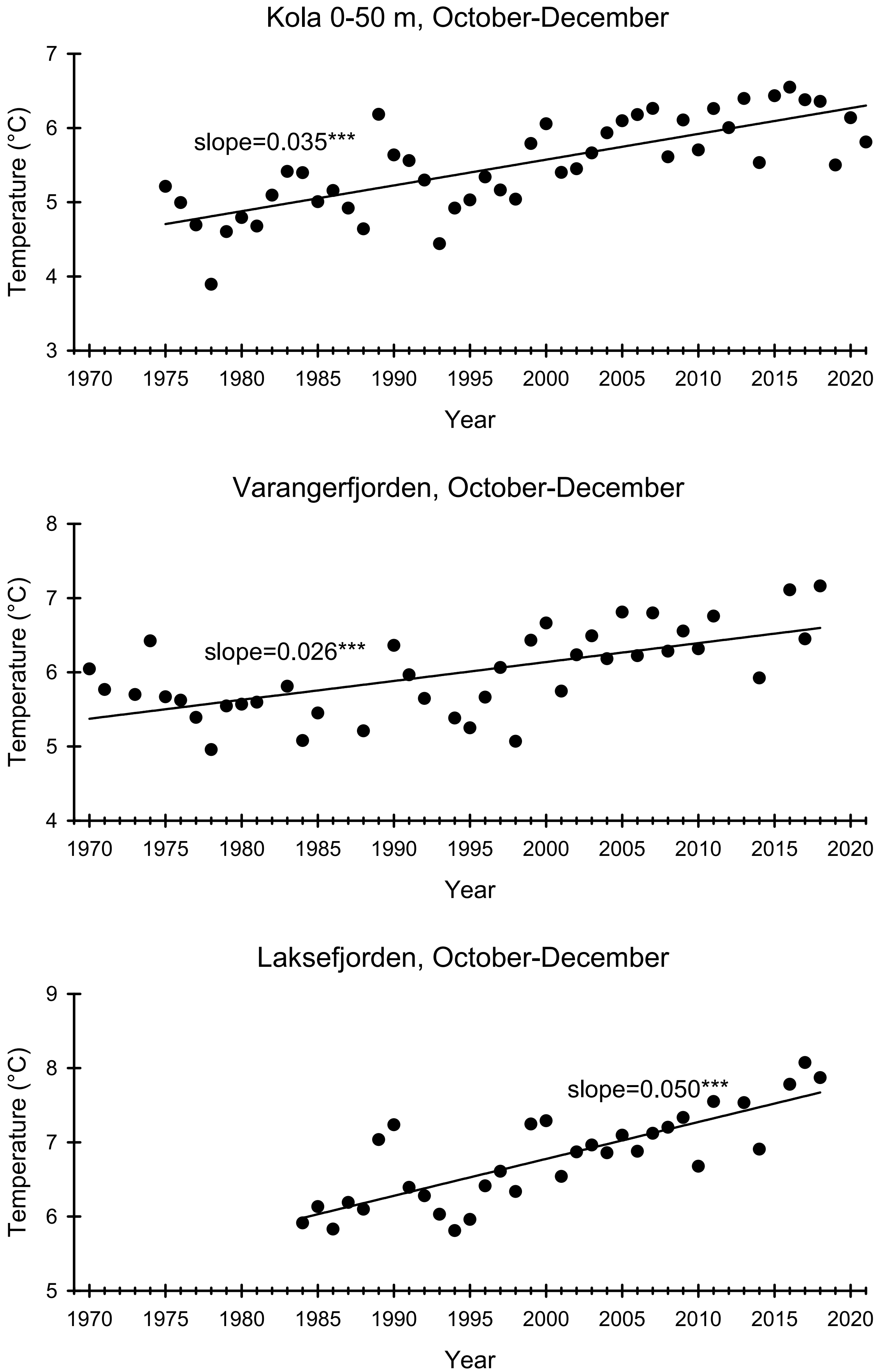

Figure 32. Increasing long-term trends in the mean sea temperature for October-December period in Laksefjorden, Varangerfjorden and in Kola (0-50 m) (Russia). Source; IMR (Norway), VNIRO (Russia).

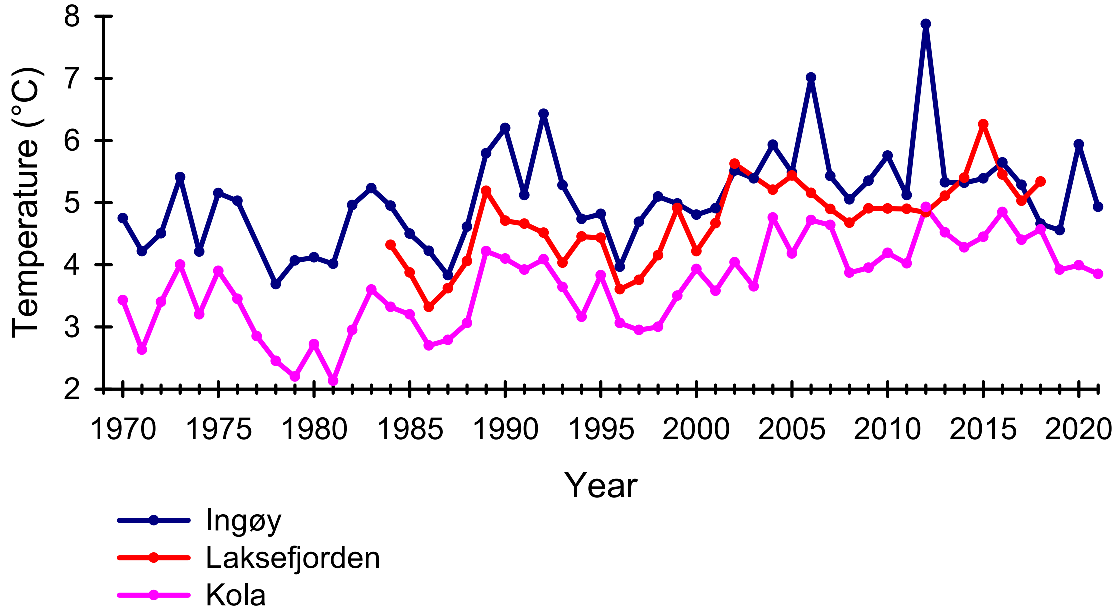

Figure 33. Annual mean long-term sea temperatures in May month in Ingøy, Laksefjorden and in Kola (0-50m) (Russia). Source; IMR (Norway), VNIRO (Russia).

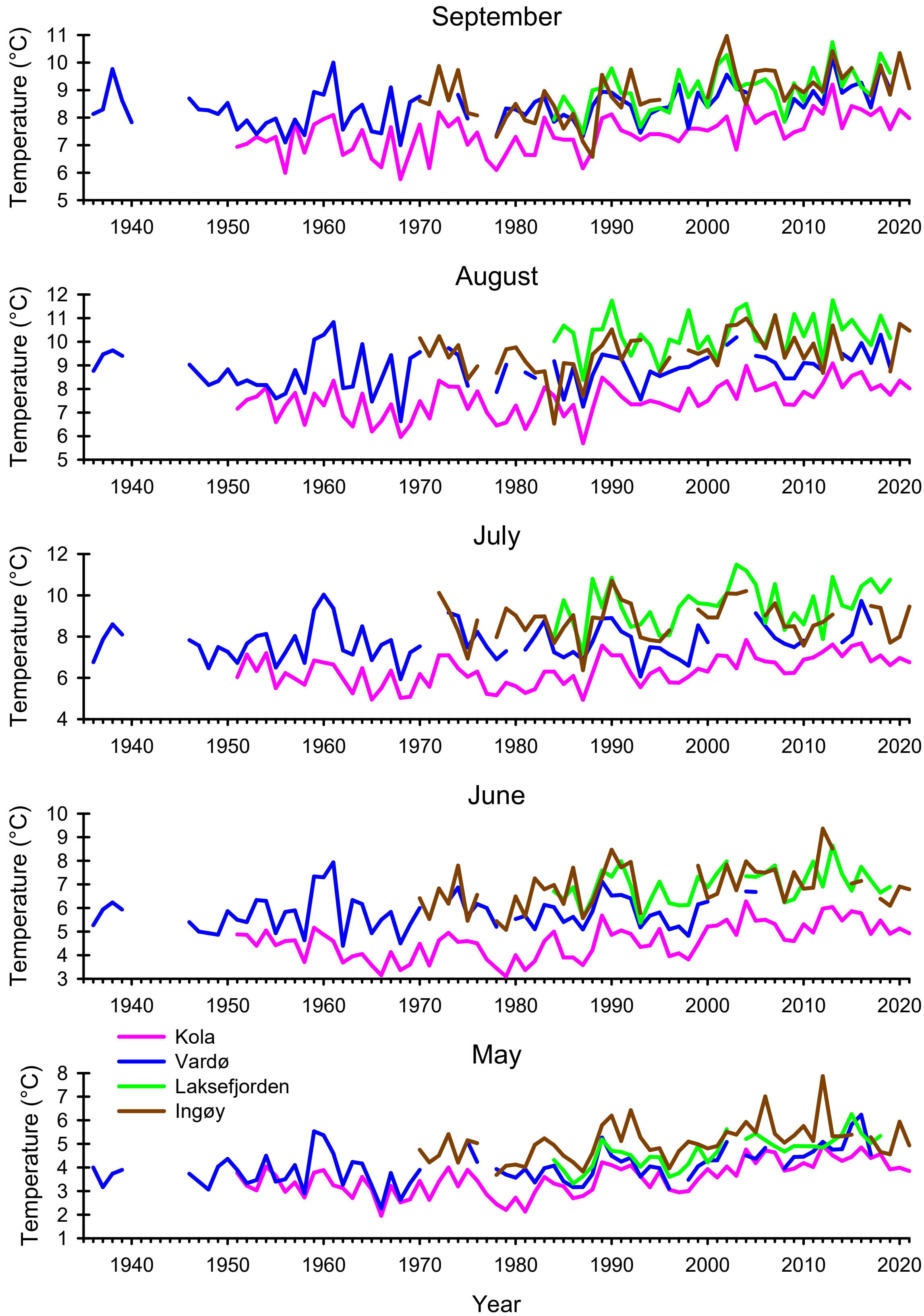

Figure 34. Mean long-term sea temperatures in summer months in Ingøy, Laksefjorden, Vardø and in Kola (0-50m) (Russia). Source; IMR (Norway), VNIRO (Russia).

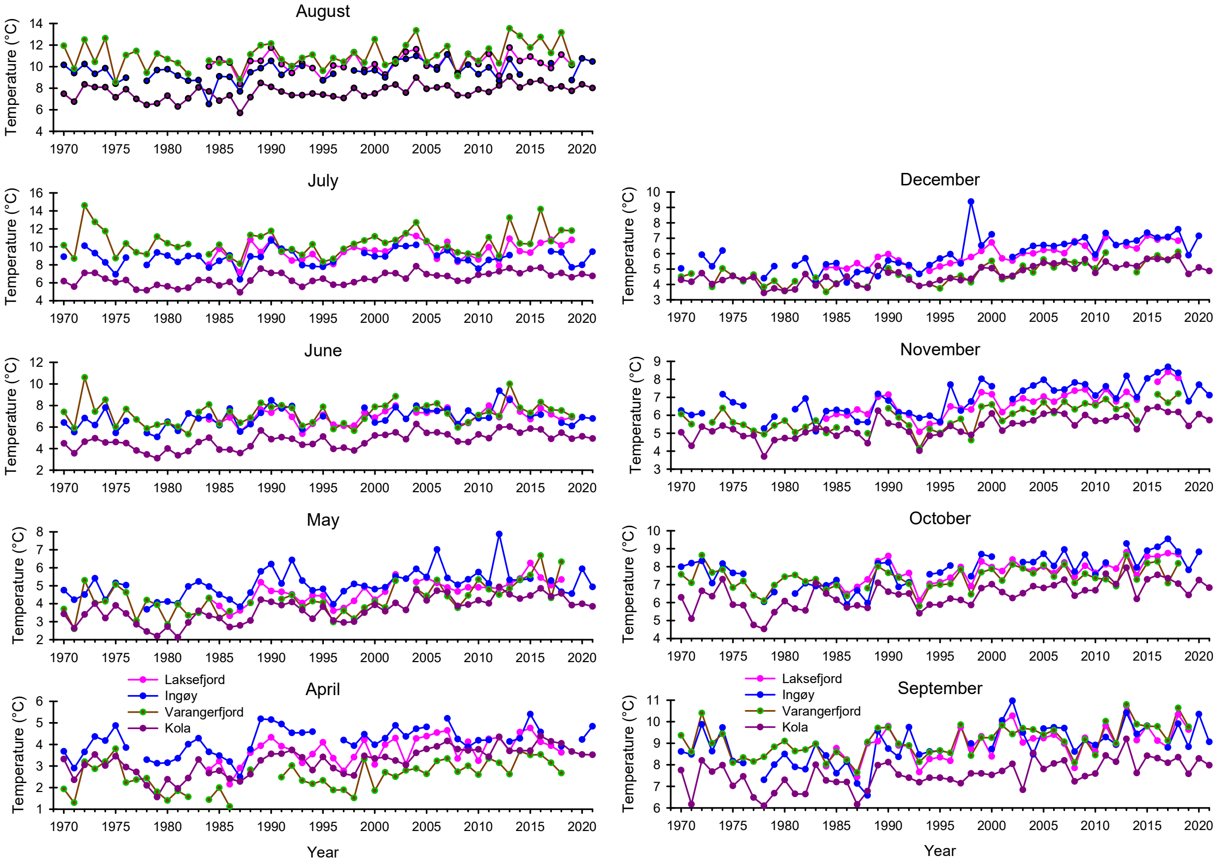

Figure 35. Mean annual long-term sea temperatures for the months from April to the end of the year in Laksefjord, Ingøy, Varangerfjord and Kola (0-50m) (Russia). Source; IMR (Norway), VNIRO (Russia).

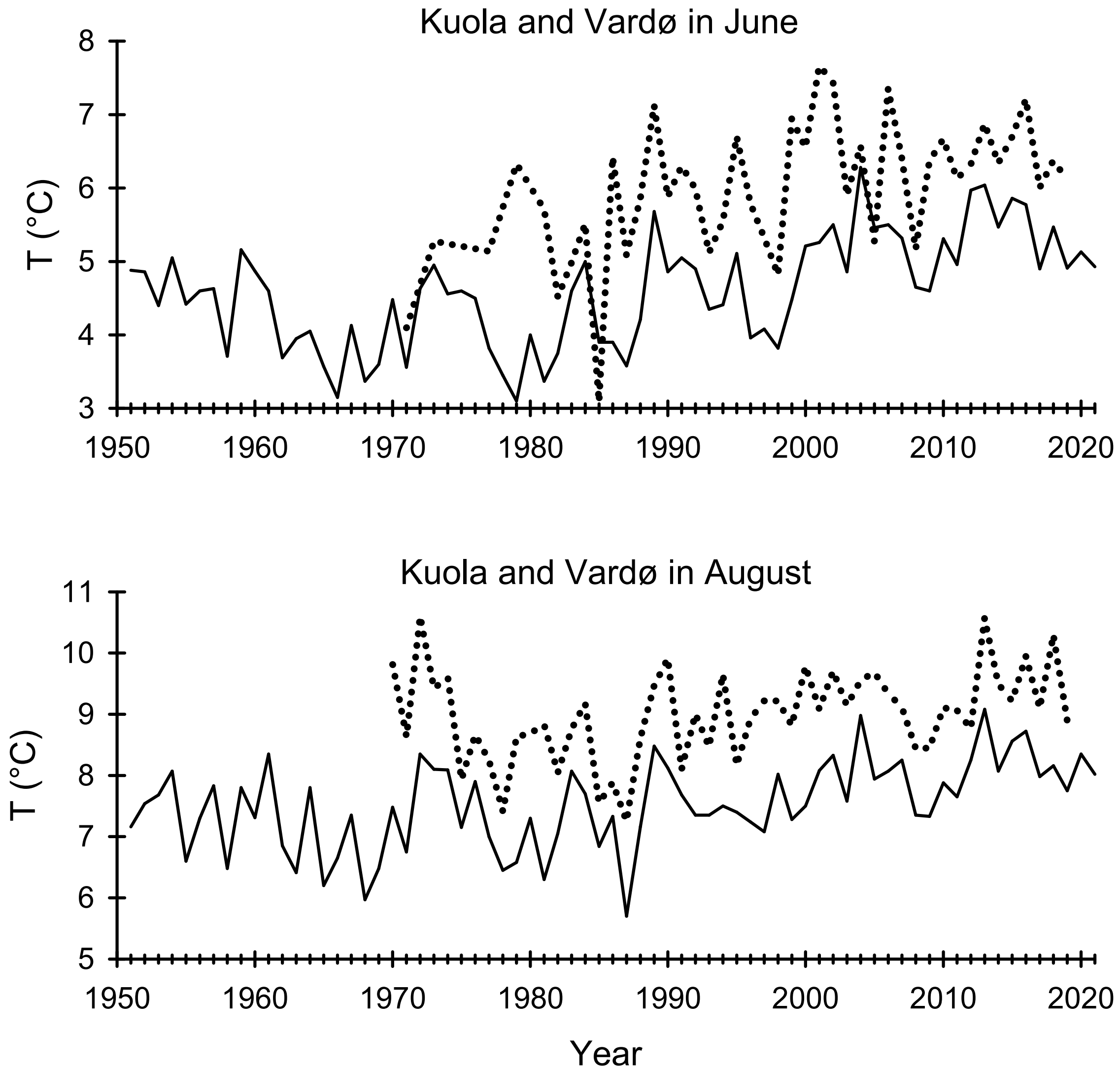

Figure 36. Mean long-term sea temperatures in August in Vardø (dotted line) and in Kola (0-50 m) (continuous line). Source; IMR (Norway), VNIRO (Russia).

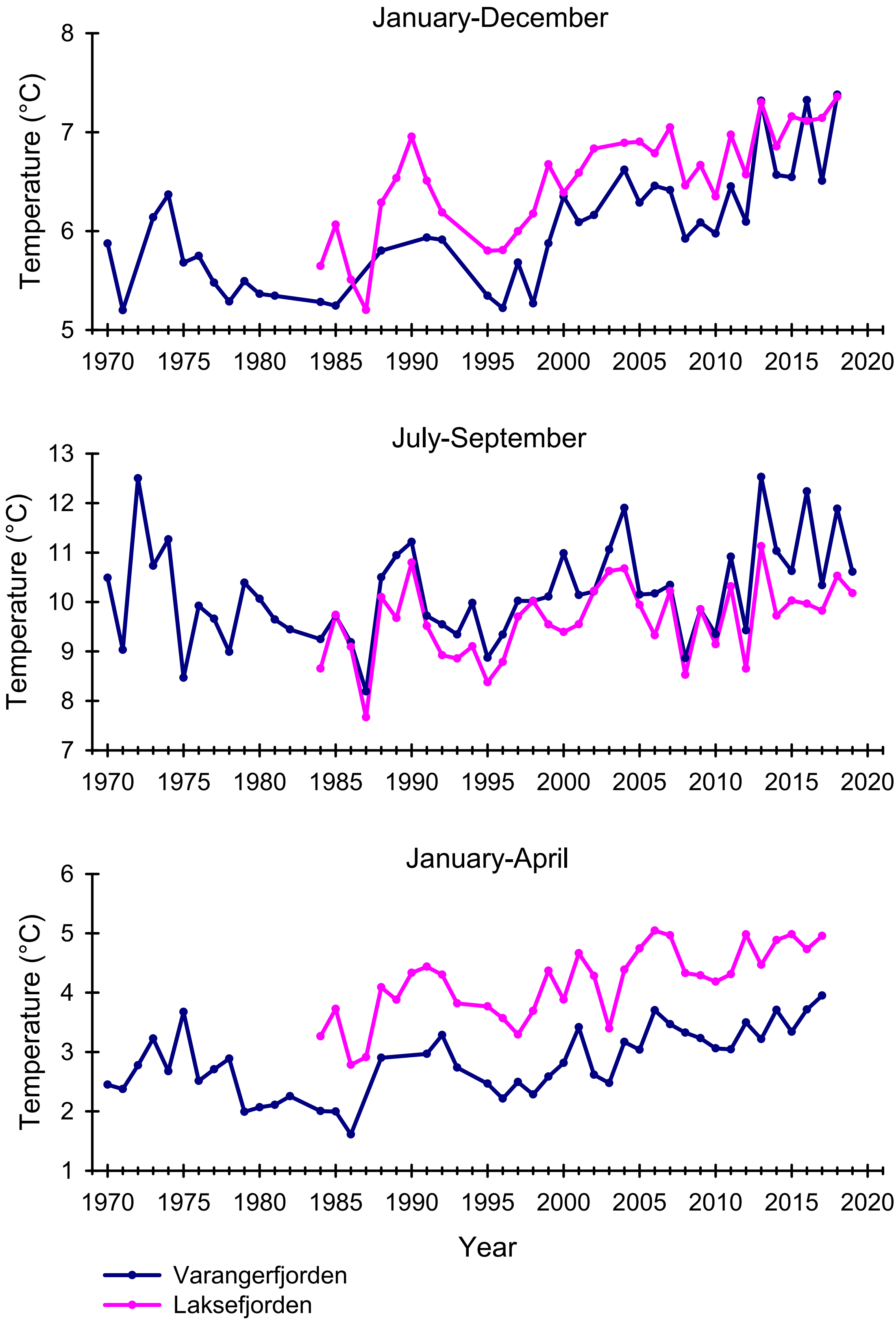

Figure 37. Mean long-term sea temperatures in the periods of January-April and July-September in Laksefjorden and Varangerfjorden. Source; IMR (Norway), VNIRO (Russia).

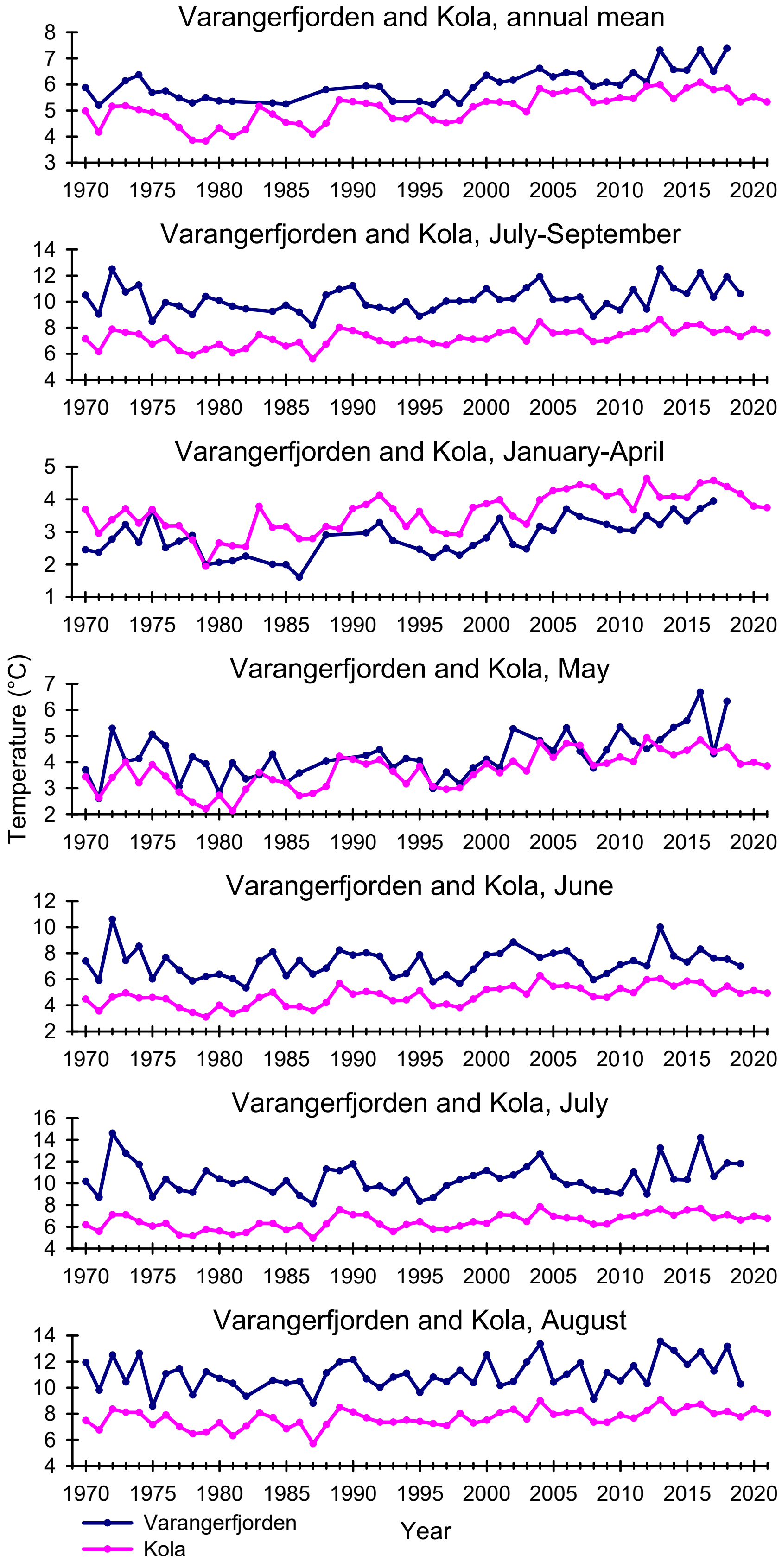

Figure 38. Mean long-term sea temperatures in May, June, July, August and for the periods January-April and July-September and for the whole year in Varangerfjorden and Kola (0-50 m). Source; IMR (Norway), VNIRO (Russia).

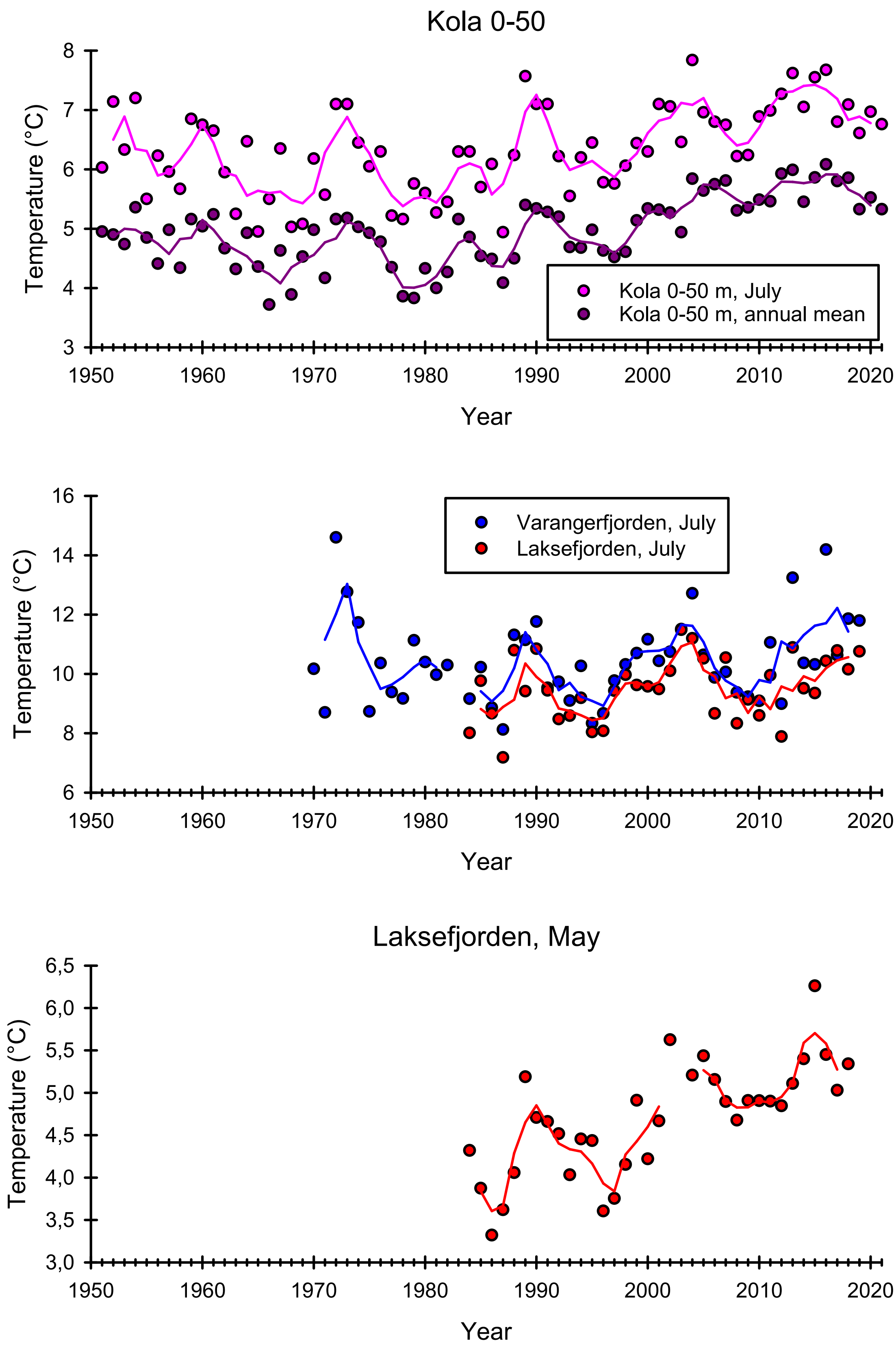

Figure 39. Annual simultaneous variations in the sea temperatures in Laksefjord, Varangerfjorden and in Kola (0-50 m) (Russia). Source; IMR (Norway), VNIRO (Russia).

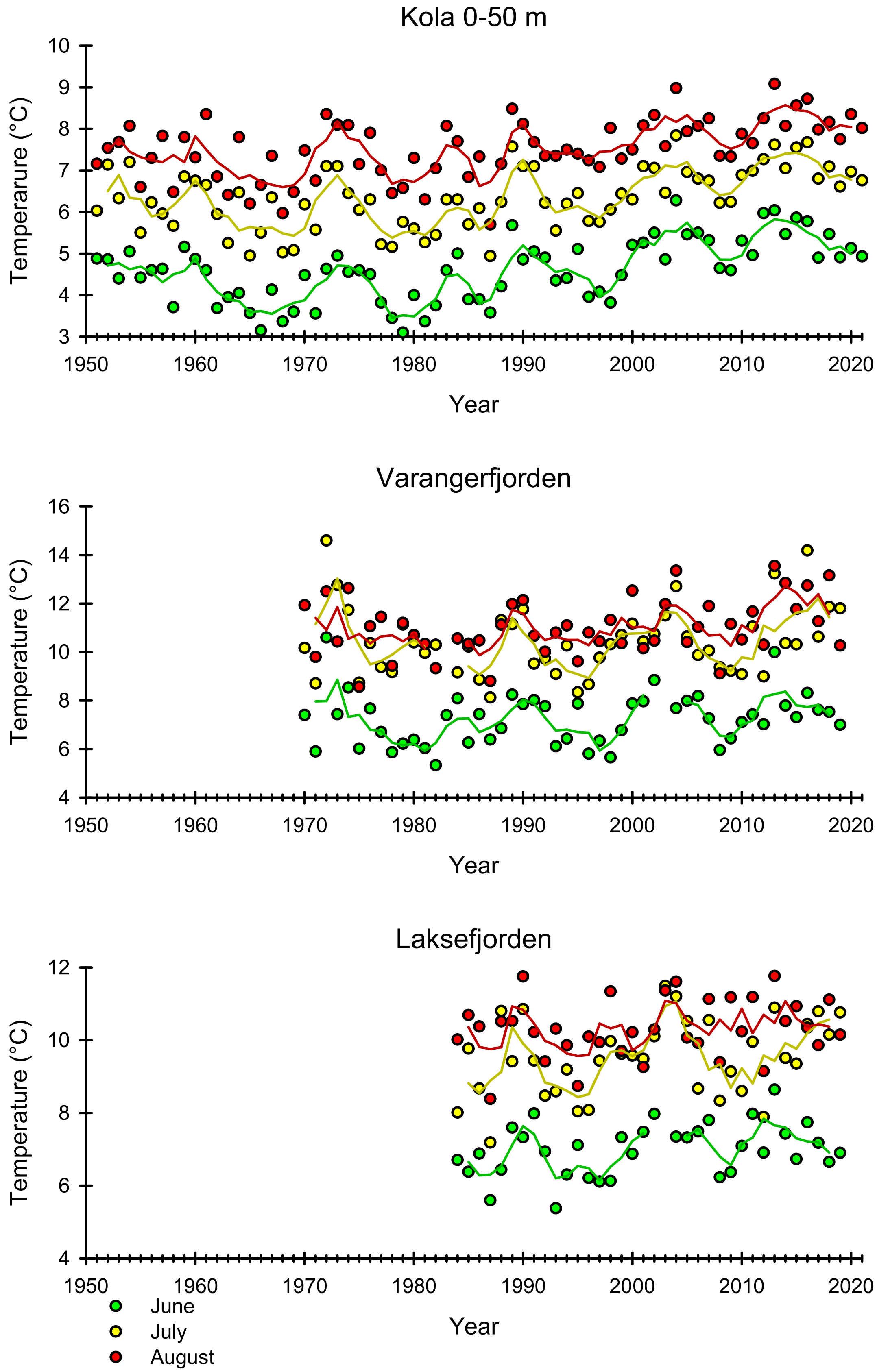

Figure 40. Annual simultaneous variations in the sea temperatures for June, July and August in Laksefjord, Varangerfjorden and in Kola (0-50 m) (Russia). Source; IMR (Norway), VNIRO (Russia).

10. Sea and river temperatures and catch timing in the River Tana

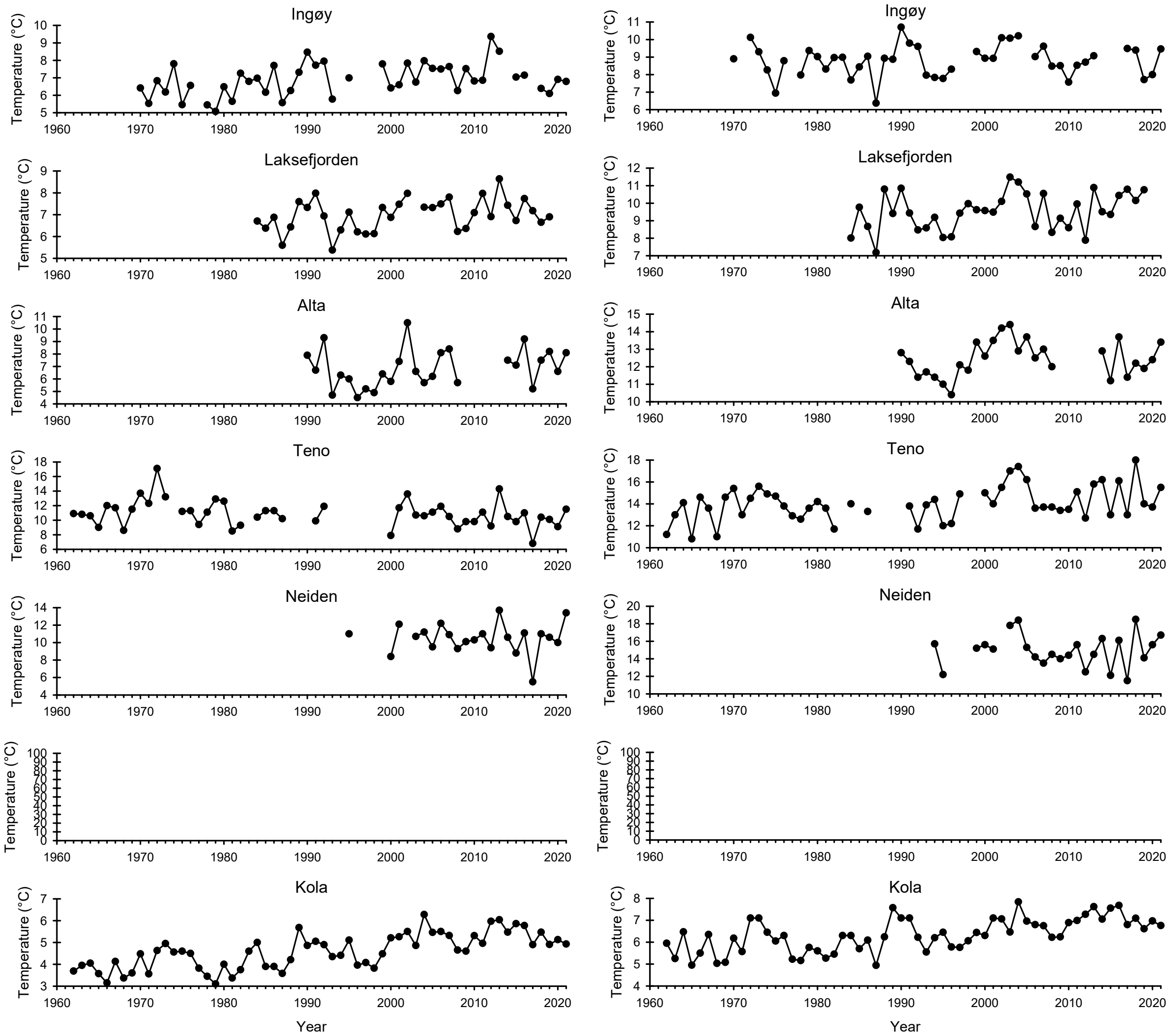

Figure 41. Long-term sea temperatures in June (figure on the left) and in July (on the right) at sea in Ingøy, Laksefjorden, Kola (0-50m) and in the rivers Alta, Tana and Neiden. Source; IMR (Norway), NVE (Norway), VNIRO (Russia).

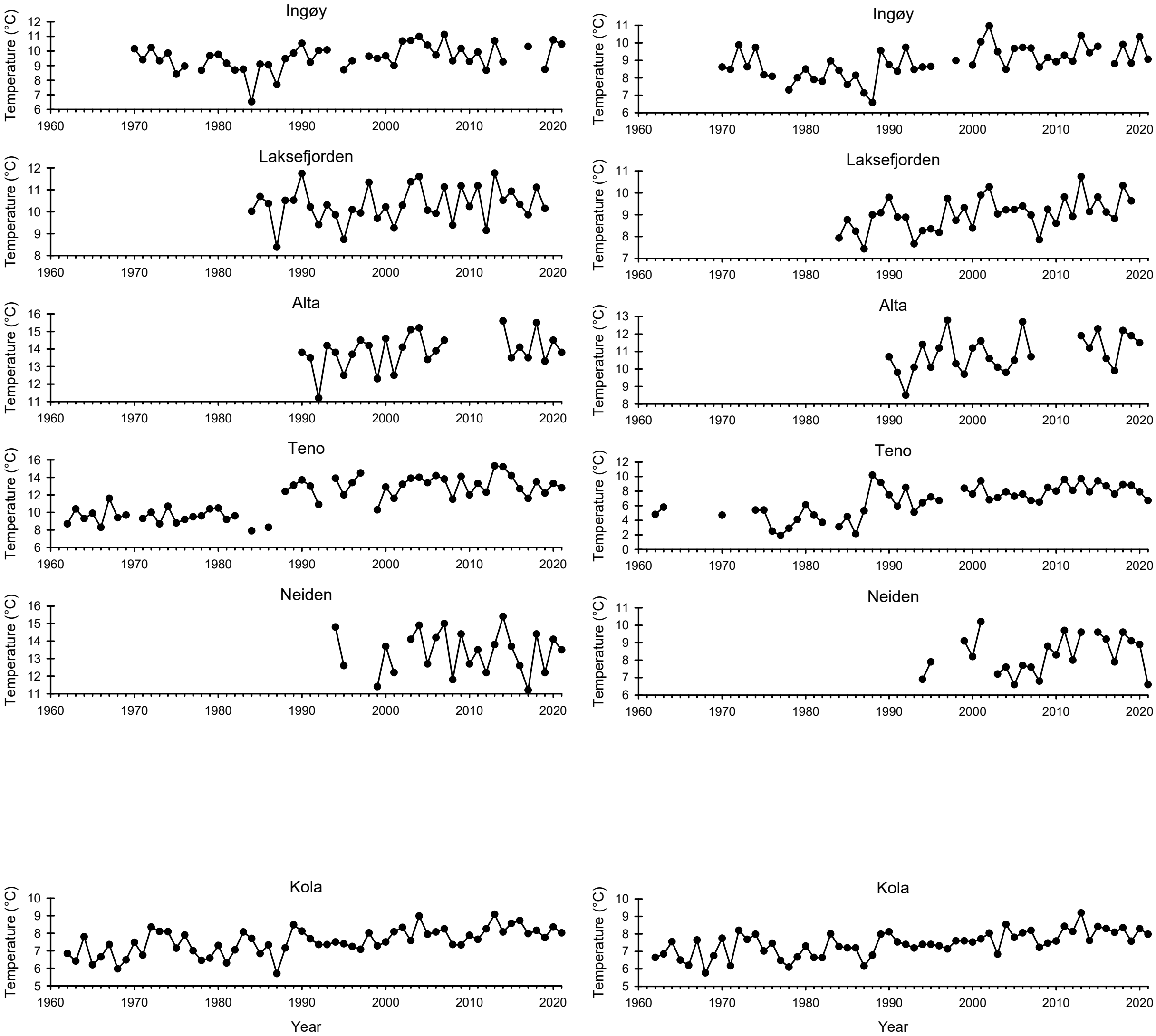

Figure 42. Long-term sea temperatures in August (figure on the left) and in September (on the right) at sea in Ingøy, Laksefjorden, Kola (0-50m) and in the rivers Alta, Tana and Neiden. Source; IMR (Norway), NVE (Norway), VNIRO (Russia).

Generally, in multi-seawinter salmon three sea winter old salmon are ascending earliest into the River Tana watershed. They start to migrate into the River Tana late May but the most important ascending period is the whole June month. It has found that the ascending period has taken place nowadays earlier than in 1970´s. Reason for that is the fact that sea temperatures in Laksefjord have increased significantly in May month (Figure 31) reflecting from the same kind of warming in sea surface waters within wider coastal areas in North Norway like in Ingøa (Figure 30). Combined into the higher sea water temperatures in North Norway late in spring, ice break-up has taking place earlier in the River Tana compared to ice breaking in 1970´s. Figure 43 indicates clearly the significant correlation between the median date of capture for three sea-winter salmon caught in the area Teno 2 and sea surface temperature at sea in May. Figure 44 confirms the relations between sea temperatures in May and the median data of capture for previous spawning salmon. Previous spawning salmon is ascending into the River Tana even earlier than virgin 3 sea-winter salmon.

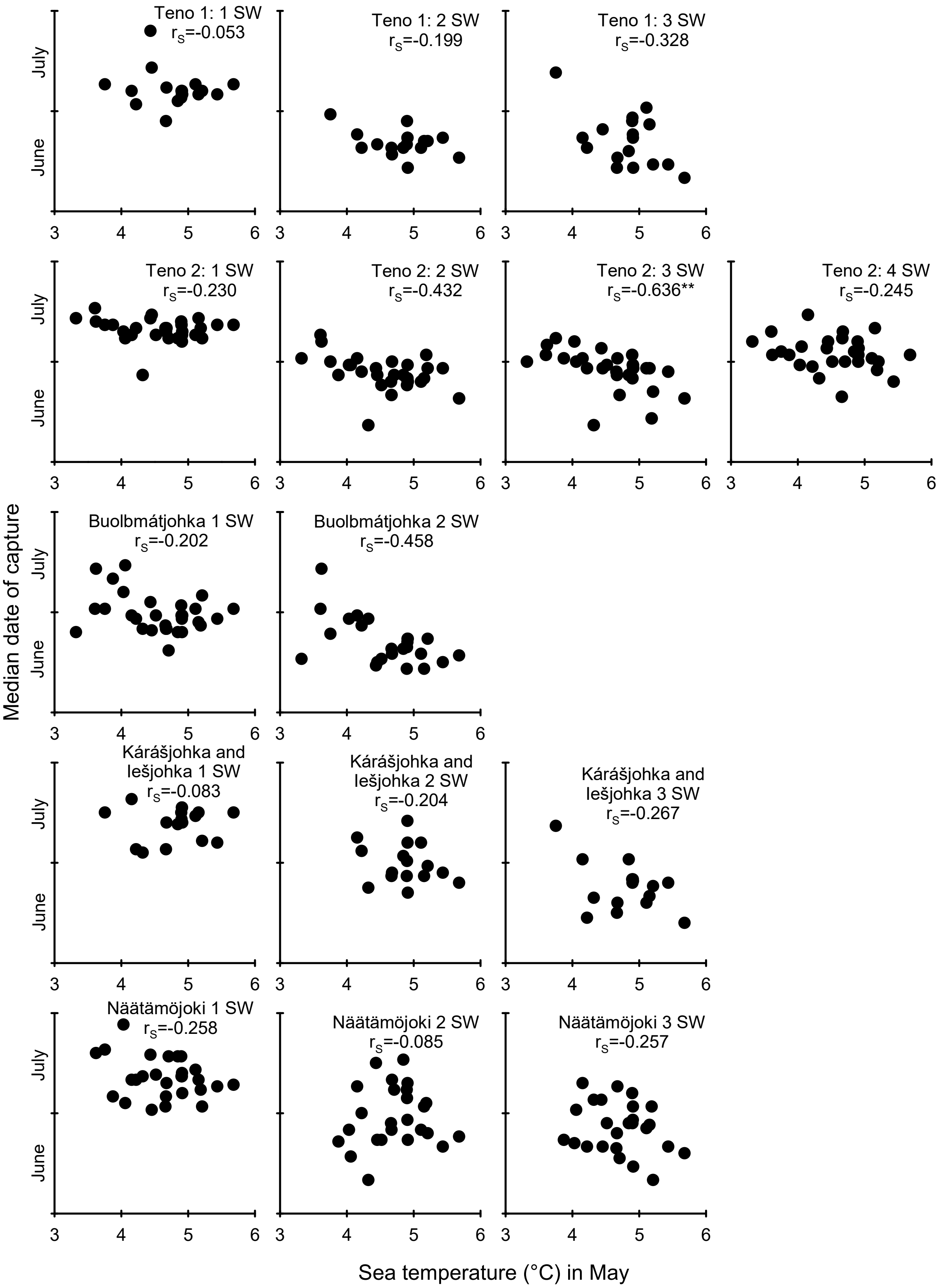

Figure 43. Mean sea temperatures in May in Laksefjorden and their influence on the median dates of capture of 1SW, 2SW, 3SW and 4SW salmon in the rivers Teno 1 (Norwegian Tana from the river mouth to Tana bru), Teno 2 (Finnish stretch from the River Tana), Buolbmatjohka (tributary to the River Tana), Karasjohka and Iesjohka (tributaries to the River Tana in Norway) and in the River Neiden (Näätämöjoki). Source; IMR (Norway), TF organization (Norway), Luke (Finland).

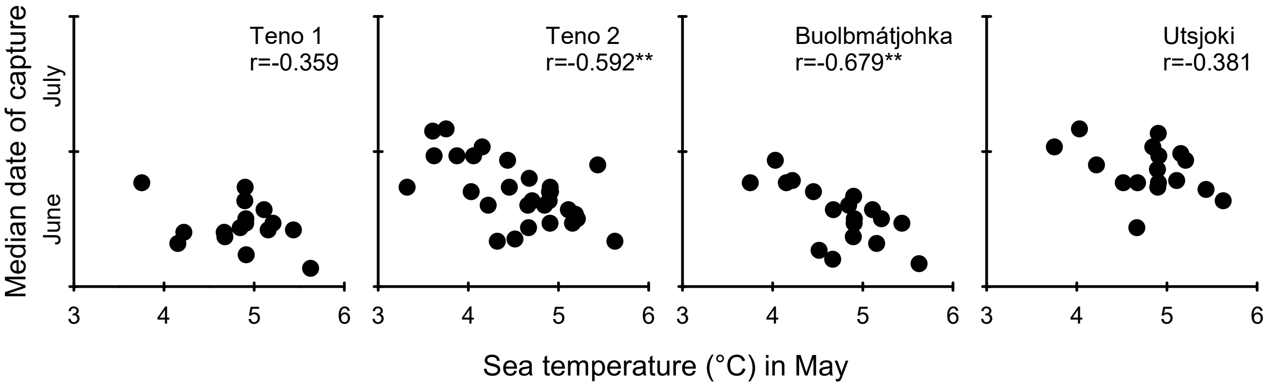

Figure 44. Mean sea temperatures in May in Laksefjorden and their influence on the median dates of capture of previous spawning salmon in the rivers Teno 1 (Norwegian Tana from the river mouth to Tana bru), Teno 2 (Finnish stretch from the River Tana), Buolbmatjohka (tributary to the River Tana) and in the River Utsjoki (tributary to the River Tana). Source; IMR (Norway), TF organization (Norway), Luke (Finland).