

Calanus, Leach, 1819, copepodite stages 1-4.

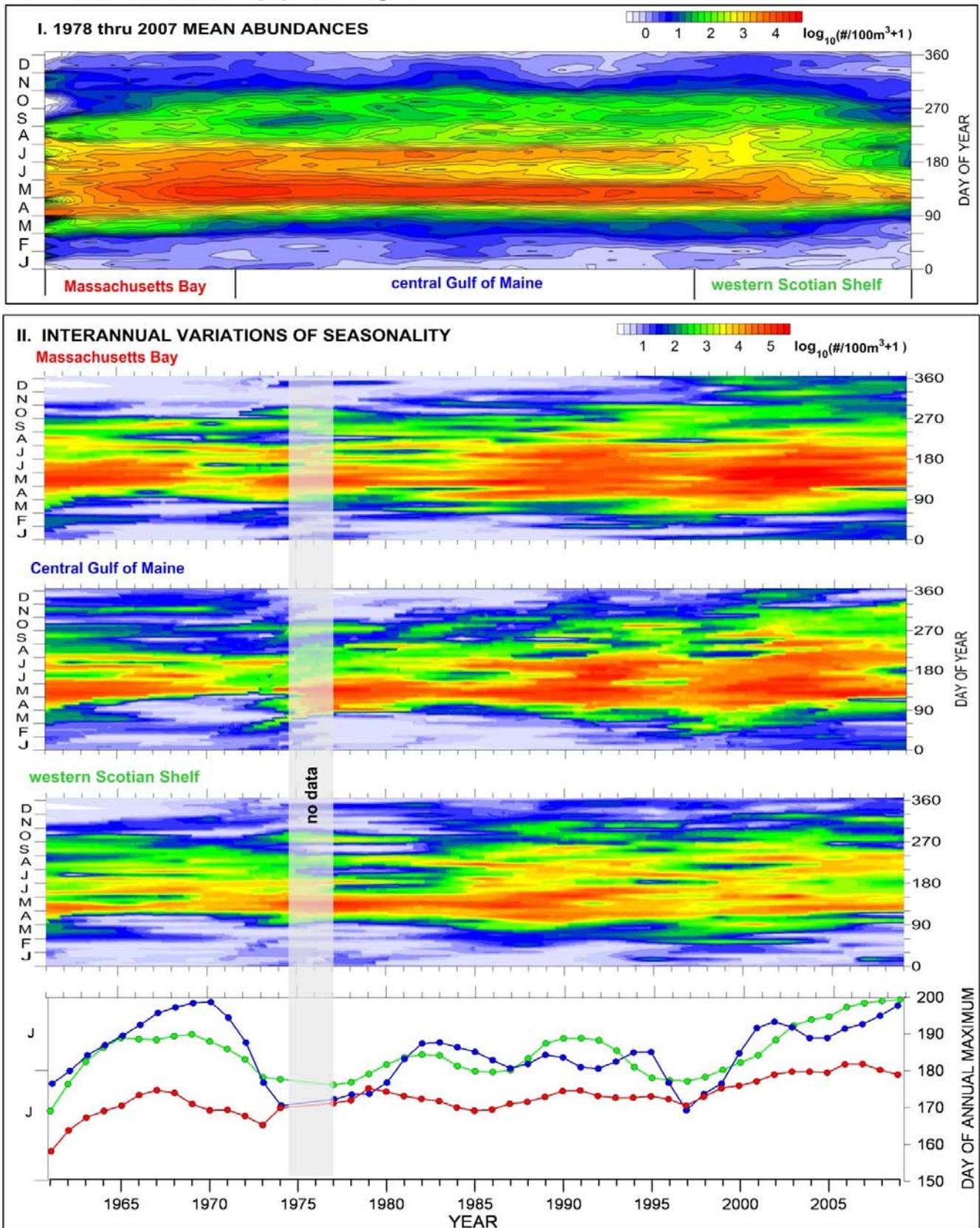


Figure 7. *Calanus* c. 1-4 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Calanus, Leach, 1819, copepodite stages 1-4.

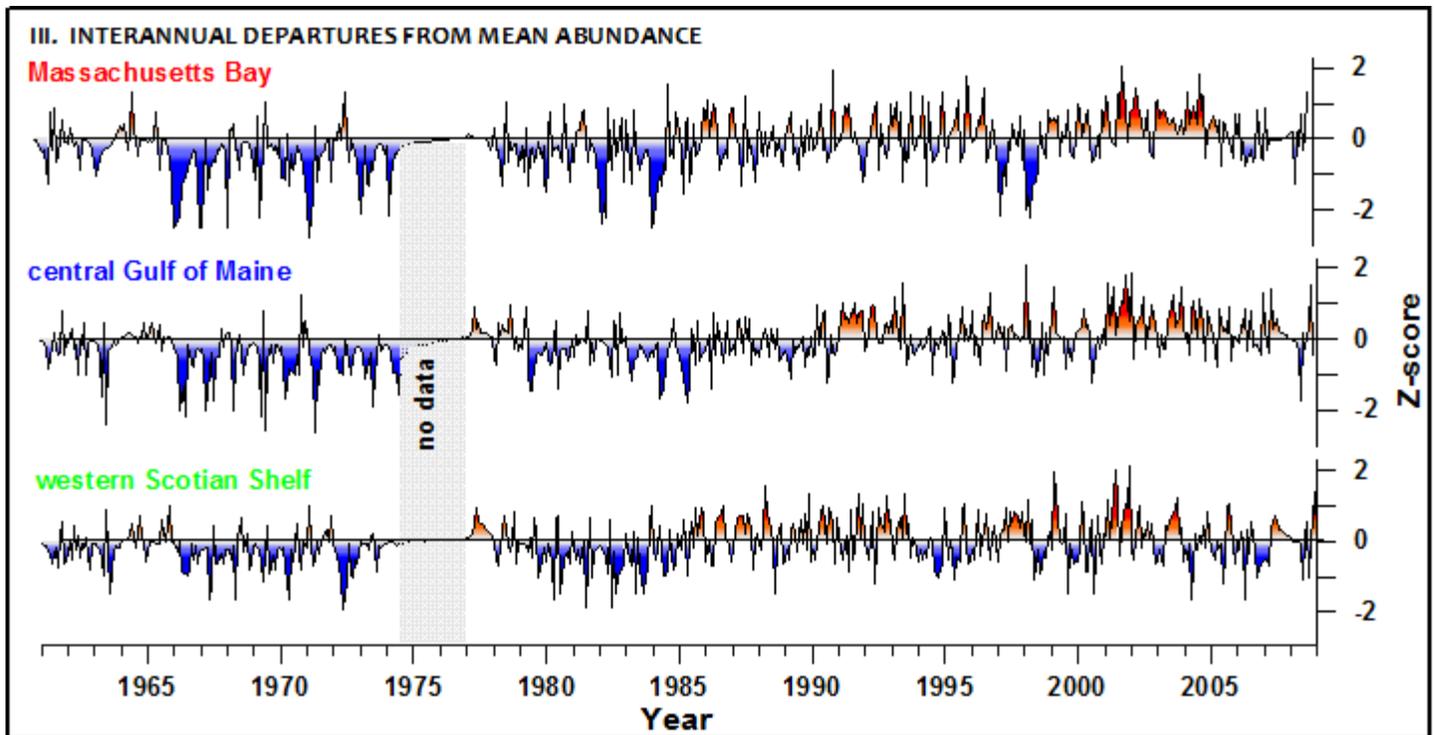


Figure 7 (cont.). *Calanus* c. 1-4 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

In CPR samples from the Gulf of Maine, the young stages of *Calanus* are primarily the early life stages of *Calanus finmarchicus*, a dominant large copepod found throughout sub-Arctic waters of the North Atlantic. Due to its large size, it is a major contributor to the annual biomass cycle in the region. *Calanus* is a key prey item essential for the sustenance of vital fisheries and the endangered North Atlantic Right Whale population.

Mean abundances increased in March from winter lows across the transect, peaking in May followed, except for the eastern end of the transect, by a lesser peak in late June. Greatest abundances occurred over outer Massachusetts Bay and the central Gulf of Maine. Peak values generally declined from west to east. In early August abundance began a decline, returning to winter levels by early October.

Relatively larger differences in the day of annual maximum between transect sections occurred from 1961 into the early 1970s than was seen during the rest of the series. A general latening of the peak was seen for the central Gulf of Maine and the western Scotian Shelf, especially after 1997.

Monthly abundance departures from the 1978-2007 base period showed negative values from 1961 into the mid-1980s, positive anomalies from 1985-2005 (except in the central Gulf of Maine), and a return to average or slightly negative conditions thereafter. Notable exceptions were the large negative Zscores in 1997 and 1998, and the mixed departures in the central Gulf of Maine from 1985 to 2002.

Centropages typicus, (Kroyer, 1849), copepodite stages 4-6.

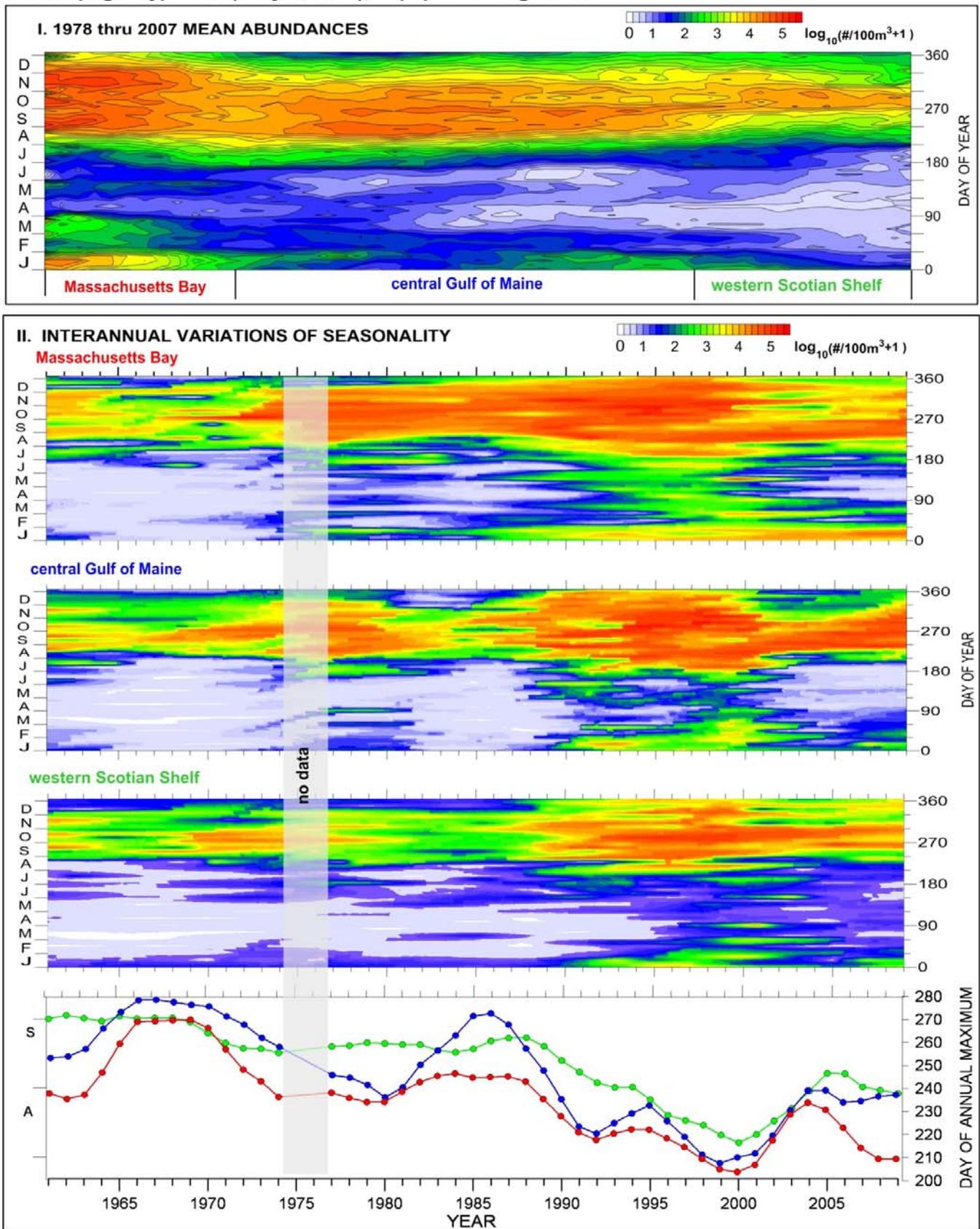


Figure 8. *Centropages typicus* c. 4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Centropages typicus, (Kroyer, 1849), copepodite stages 4-6.

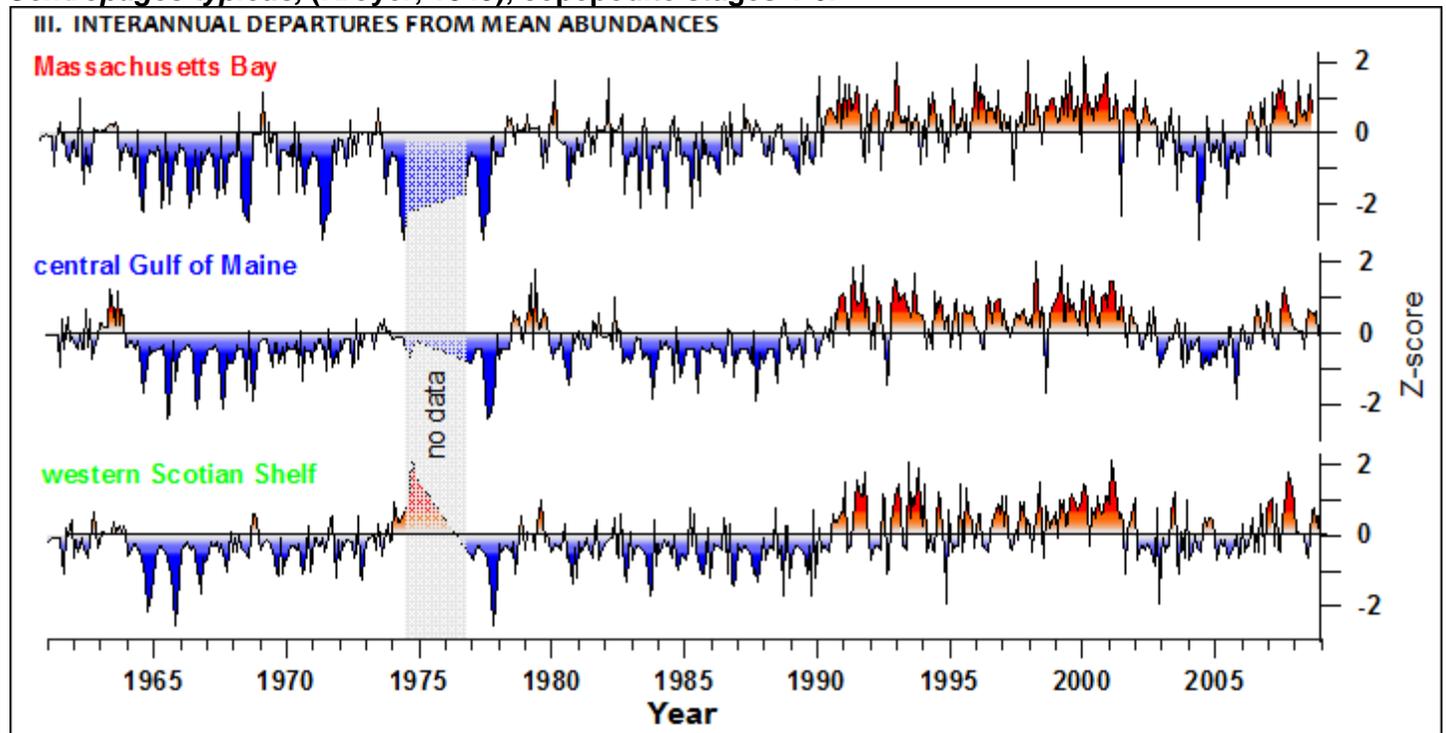


Figure 8 (cont.). *Centropages typicus* c. 4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Centropages typicus is a relatively large, omnivorous calanoid copepod. When food resources are available, temperature appears to be the key factor that determines its spatial and temporal range. Its abundance is highest in waters that range from 13° to 20°C.

High mean values occurred in Massachusetts Bay in January, as remnants of the previous year's swarm. Likewise, moderate abundances were found over the eastern portions of the central Gulf of Maine and the western extremes of the western Scotian Shelf. Moderate abundances continued in Massachusetts Bay through March. Until July, most of the transect exhibited low values. Thereafter, abundance rose rapidly in the west, more slowly in the east, and peaked in October. The peak persisted in Massachusetts Bay to nearly the end of the year, whereas a decline began on the western Scotian Shelf by the end of October.

Beginning in 1990 the seasonal pattern, which had been fairly stable during the previous three decades, changed considerably, with moderate abundances occurring for most of the January through July period in all three sections of the transect. By about 2005 this seasonality change had somewhat reverted to the pre-1990 state. The day of annual maximum abundance showed an earlying trend for all three transect sections.

The period prior to 1990 had consistently negative anomalies. From 1990-2003 the departures were consistently positive, followed by about three years of below average abundances, and then ending the series on the positive side.

Paracalanus, Boeck, 1865, copepodite stages 1-6, & *Pseudocalanus*. Boeck, 1872, copepodite stages 1-5.

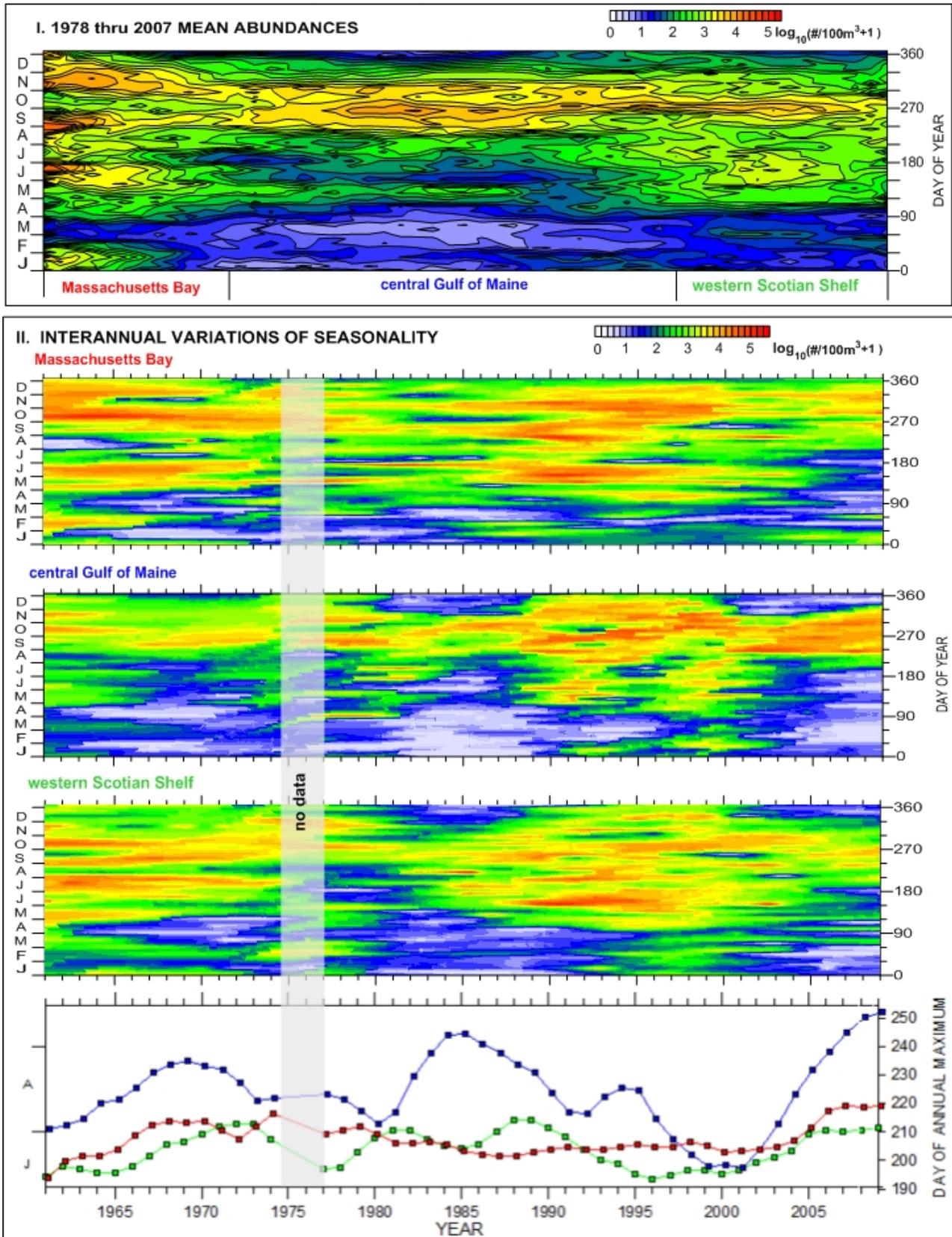


Figure 9. *Paracalanus* c.1-6 & *Pseudocalanus* c.1-5 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Paracalanus, Boeck, 1865, copepodite stages 1-6 & *Pseudocalanus*, Boeck, 1872, copepodite stages 1-5.

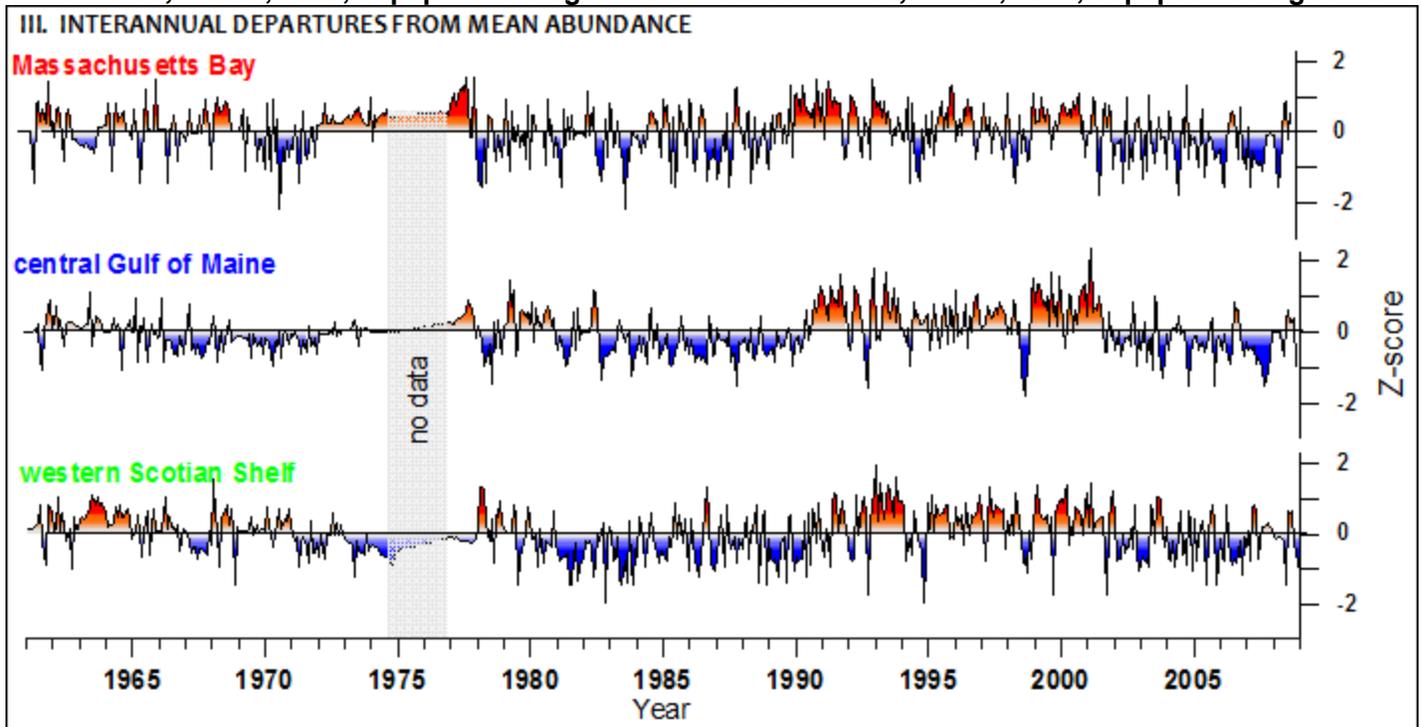


Figure 9 (cont.). *Paracalanus* c.1-6 & *Pseudocalanus* c.1-5 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

To expedite the identification and staging of these two similar sized and shaped copepod species, adults of *Pseudocalanus* were enumerated (see below), but all other stages from the two species were collectively assigned to this one category. These relatively small copepods play an important role in the trophic ecology of temperate and boreal pelagic ecosystems. They are an important prey item of several larval fish species.

Mean abundance of these copepods increased from their winter low in early spring and become common inshore at both ends of the transect by April. Abundance was highest in Massachusetts Bay where three distinct pulses occurred during the year. These inshore concentrations spread across the central Gulf of Maine during summer and transect abundance peaked during early autumn. Numbers remained high through the autumn months until a sharp decline was observed from December to January, except for Massachusetts Bay waters, where it sometimes remained abundant till mid-February.

Seasonality of these copepods in Massachusetts Bay and the western Scotian Shelf remained relatively steady during the series. However, the central Gulf of Maine day of annual maximum values showed considerable variation with earlier peaks centered in 1961, 1980, and 2000, and later peaks centered in 1969, 1985, and 2008.

Anomalies were positive throughout the Gulf of Maine during the early 1960s. Departures were variable from 1965 until a sustained low period was measured in the mid to late 1980s. From approximately 1990-2001 positive anomalies dominated, followed by negative values to near the end of the series.

Calanus finmarchicus, (Gunner, 1765), copepodite stages 5-6.

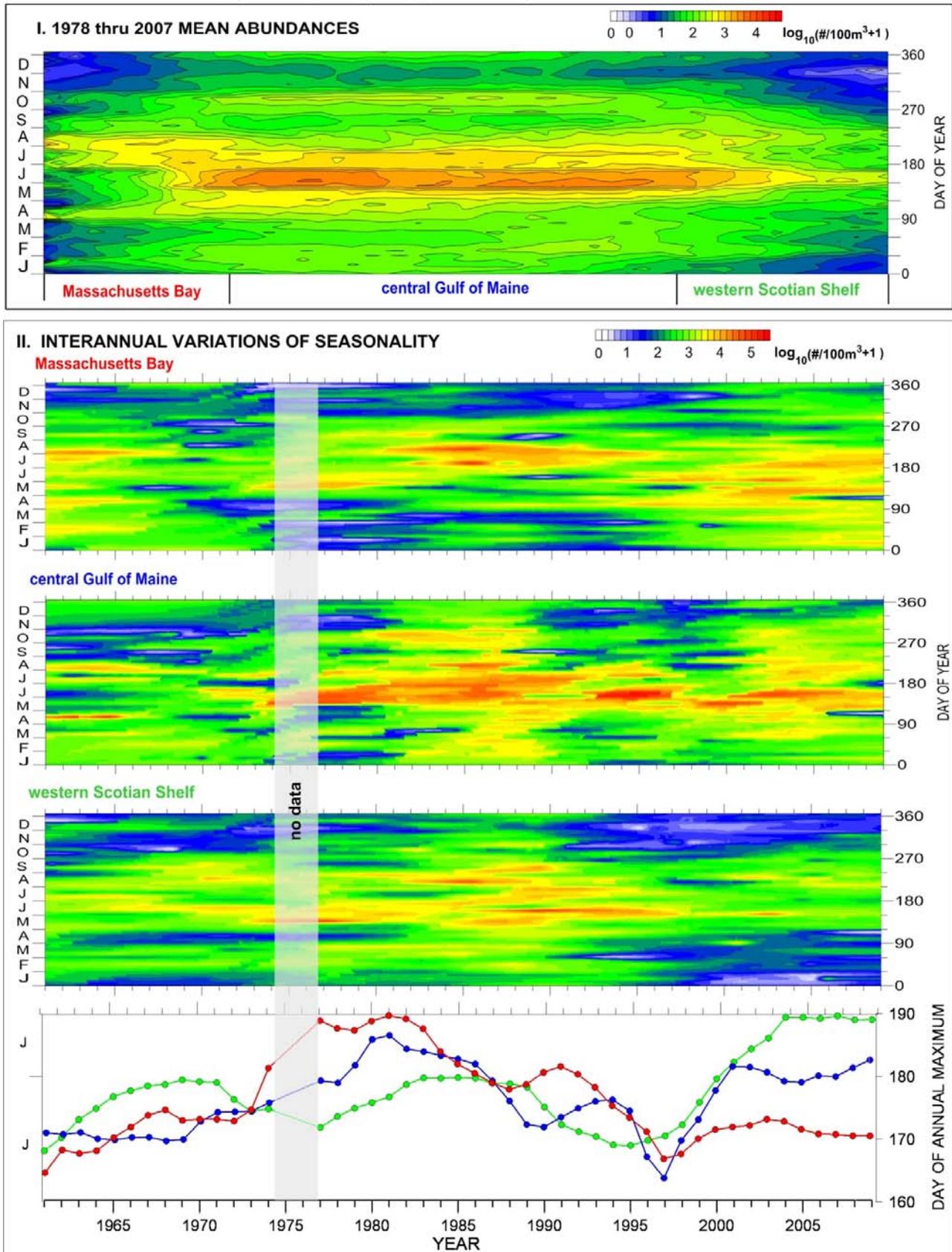


Figure 10. *Calanus finmarchicus* c.5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Calanus finmarchicus, (Gunner, 1765), copepodite stages 5-6

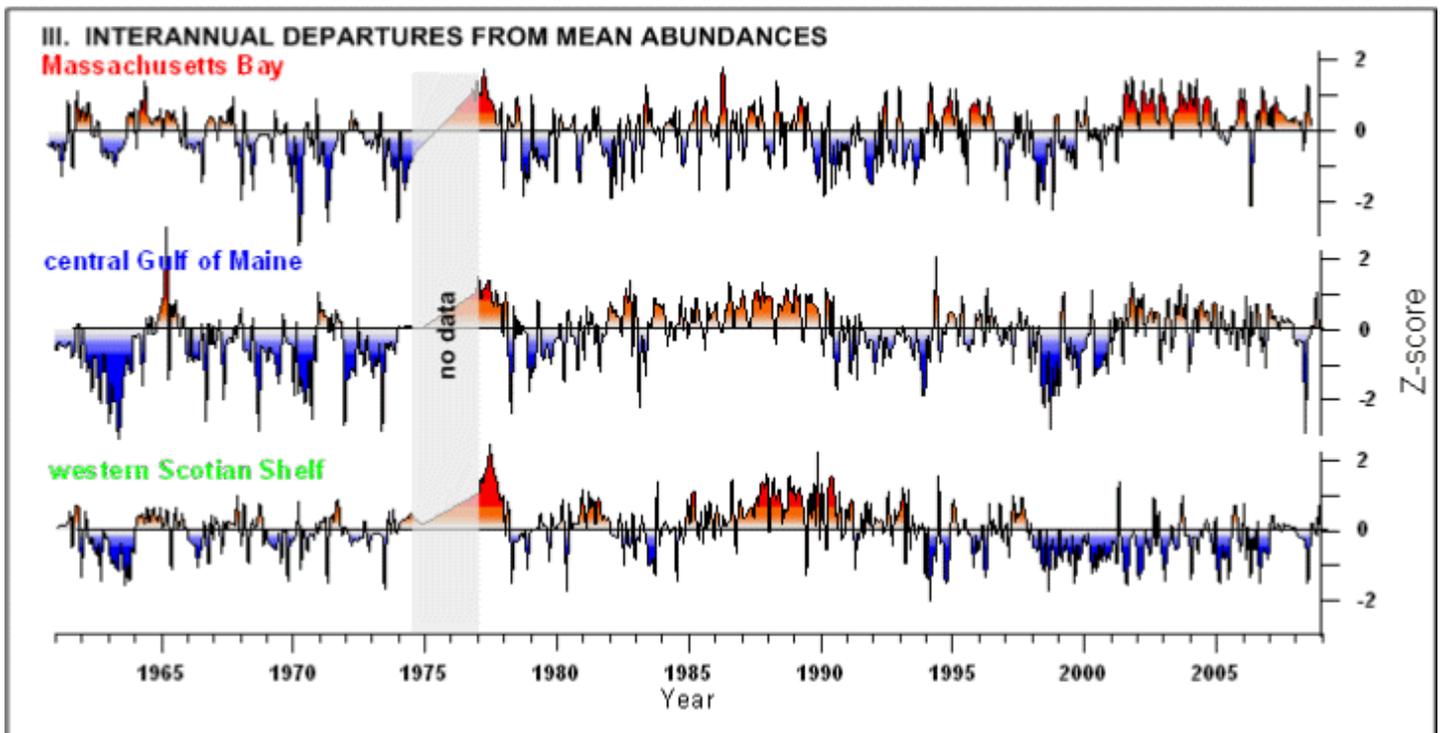


Figure 10 (cont.). *Calanus finmarchicus* c.5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

These copepods play a key role in the Gulf of Maine food web transferring energy from primary producers to upper trophic levels. They overwinter in the deep water basins as stage 5 copepodites that rise to the surface layers in early winter, molt to the adult stage, and begin to reproduce. Some individuals are transported onto Georges Bank, while others remain and either spawn a second generation or enter dormancy. Their life cycle is also dependent on external processes, e.g., restocking from upstream sources.

Mean abundance began to increase in early winter with higher numbers located in the central Gulf of Maine. Abundances increased through the spring and reached maximum levels in late spring-early summer. The concentrations advanced inshore into Massachusetts Bay for a brief period in August. Numbers declined slowly thereafter until the annual minimum was reached by late autumn.

Variation in seasonality occurred for all three transect sections. Annual abundance peaks in Massachusetts Bay and the central Gulf of Maine occurred in mid-June from 1961-1973, but occurred about 15 days later from the late 1970s – 1984. From then until 1997, peaks occurred earlier, followed by a latening in the central Gulf of Maine. Western Scotian Shelf timing was fairly steady until 1995 when latening amounted to nearly 20 days by 2008.

Anomalies in the central Gulf of Maine were mostly negative during the 1960s and 1970s. Positive departures occurred during the 1980s over the central Gulf of Maine and western Scotian Shelf, and after 2001 in the western two sections. Persistent lows occurred in these sections in the late 1990s, and in the western Scotian Shelf section until the end of the series. Temporal coherence between transect sections is less obvious for this taxon than for the previous, more abundant taxa.

Pseudocalanus, Boeck, 1872, copepodite stage 6.

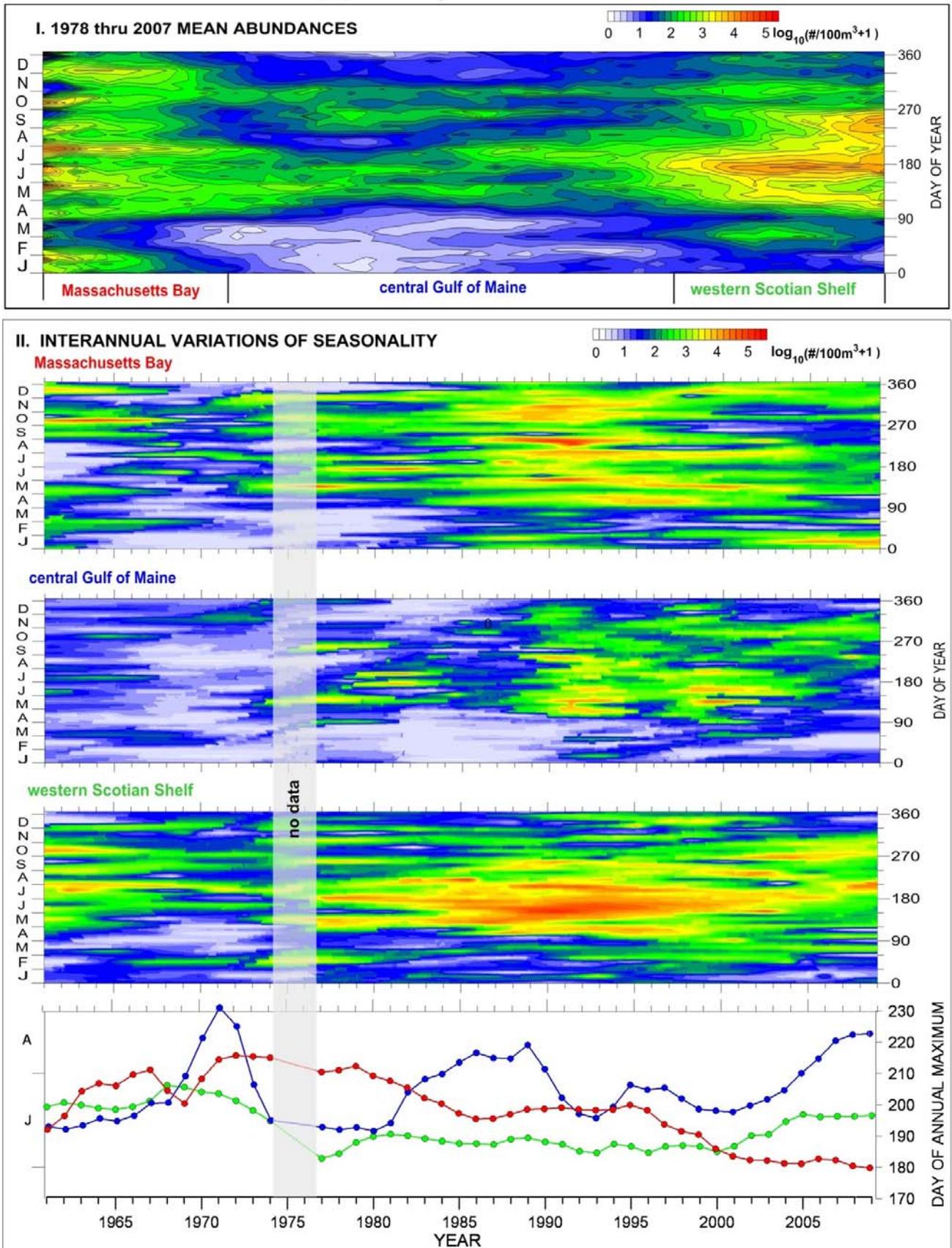


Figure 11. *Pseudocalanus* c. 6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Pseudocalanus, Boeck, 1872, copepodite stage 6.

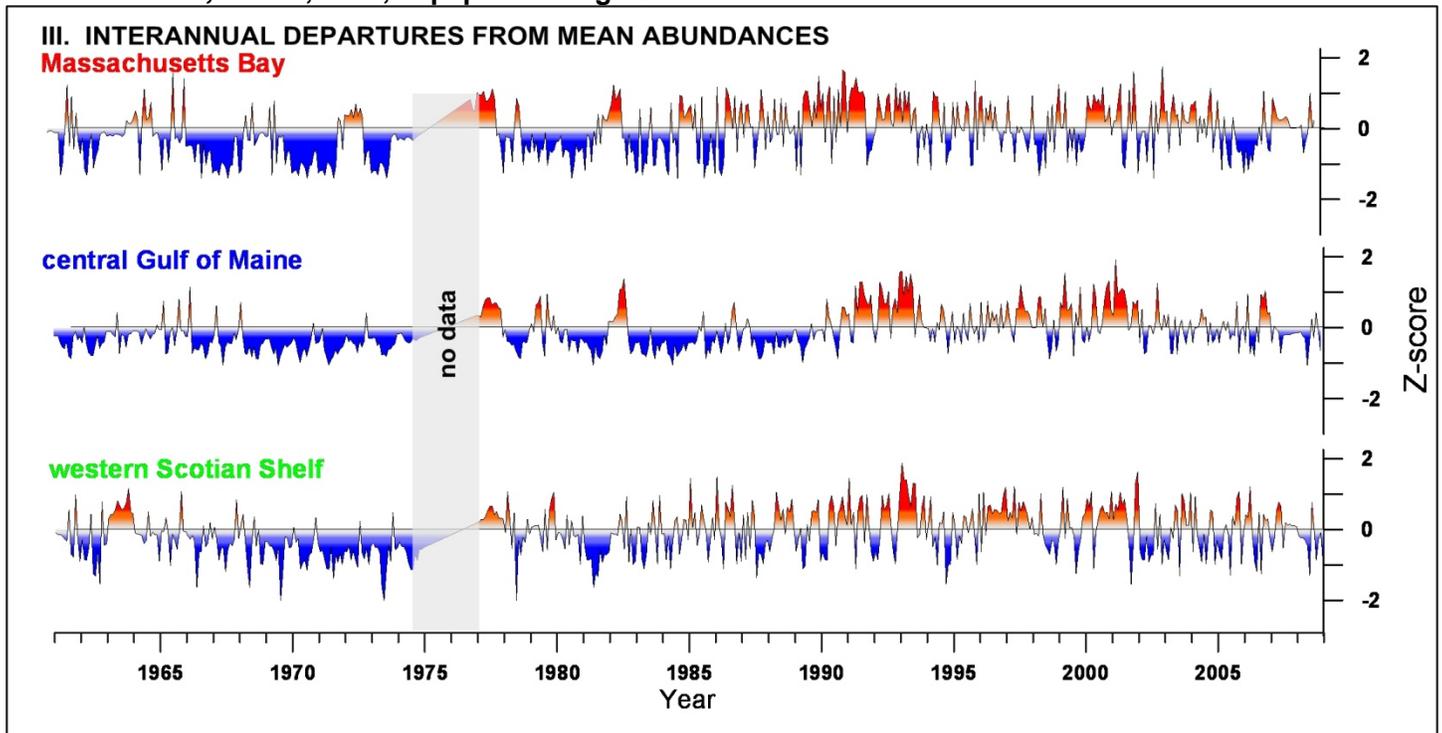


Figure 11 (cont.). *Pseudocalanus* c. 6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Pseudocalanus is a northern genus of small calanoid copepod that have a widespread distribution. There are two species common in the Gulf of Maine: *P. moultoni* (more inshore) and *P. newmani* (more offshore). Since they cannot be readily distinguished by visual examination alone, they are combined here. There is a large body of evidence indicating that these species are the predominant prey item of many larval fish found in northern waters.

Mean abundances were highest over the Massachusetts Bay and western Scotian Shelf sections, with the latter predominating. For Massachusetts Bay, two somewhat connected high periods existed from April to August and August through the end of the year, extending through the following January. These two periods were in evidence across the central Gulf of Maine, but at lower levels. On the western Scotian Shelf, abundance began to increase in early March, peaked by late June, then began to decline in amount and spatial extent, reaching seasonal lows by December.

Complicated patterns of seasonality occurred through the series. Four fairly distinct periods can be seen: 1961-1967; 1967-1972; 1972-2004; and 2004-2009. Examination of the day of annual maximum suggests that these four patterns were due more to series changes in abundance than to changes in seasonal timing.

Monthly anomalies for the three sections were mostly negative prior to the mid- 1970s. In Massachusetts Bay and the central Gulf of Maine this condition persisted with slightly less consistency into the mid- to late 1980s. During this period on the western Scotian Shelf the departures were more mixed. From 1990 to about 2005 positive anomalies prevailed, after which somewhat mixed departures were seen.

Oithona, Baird, 1843, copepodite stages 4- 6.

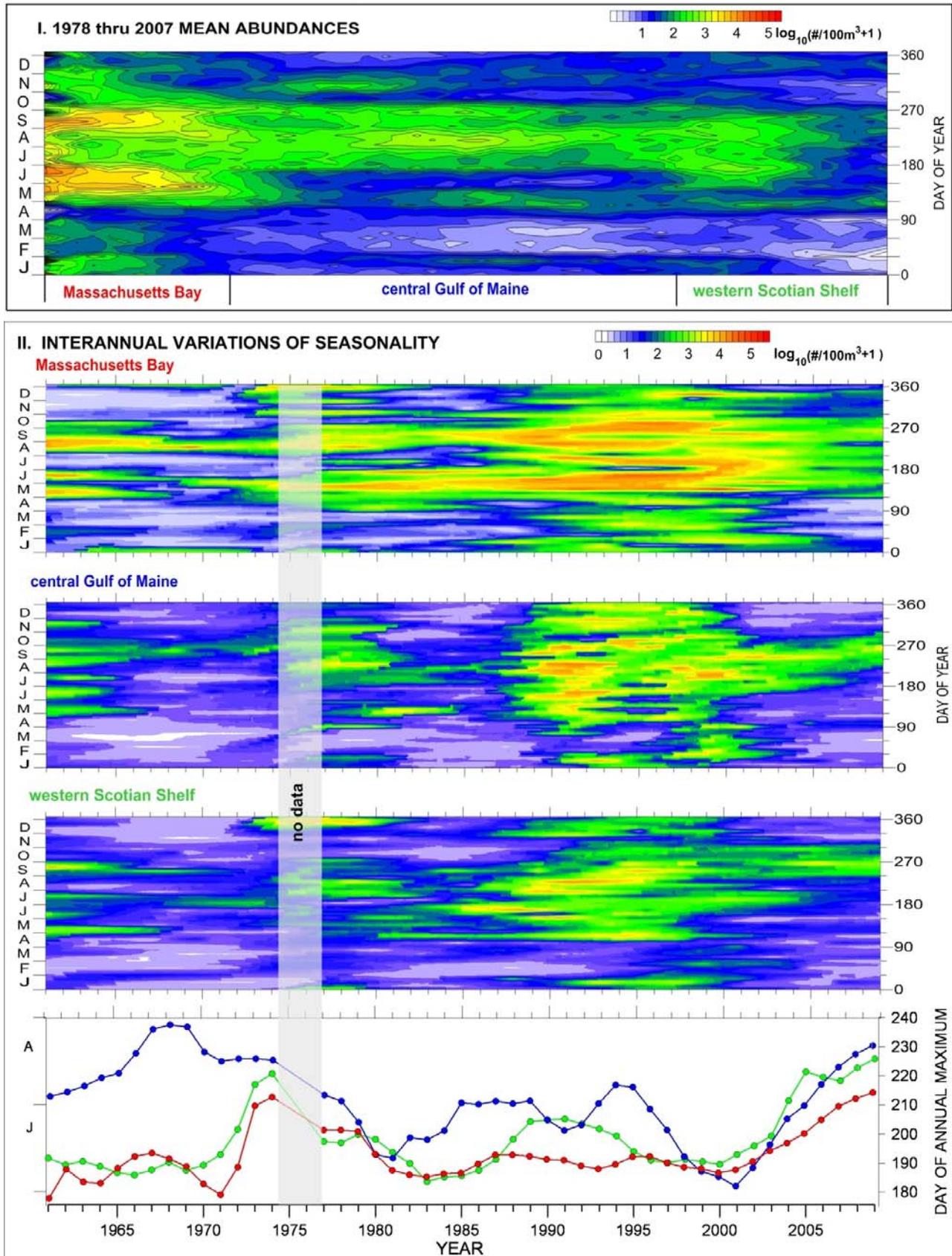


Figure 12. *Oithona* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Oithona, Baird, 1843, copepodite stages 4-6

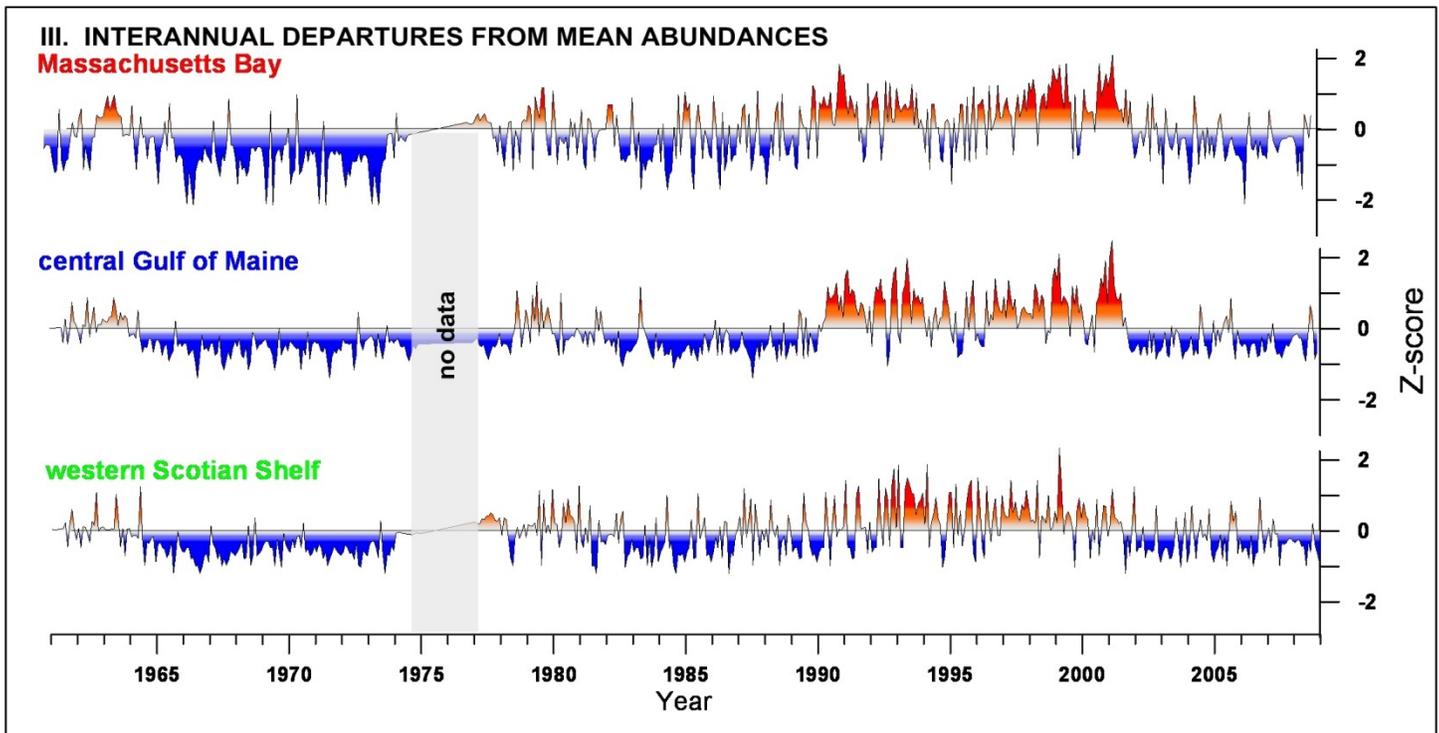


Figure 12 (cont.). *Oithona* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Oithona is one of the most abundant and ubiquitous copepods found throughout global coastal and oceanic areas. This cyclopoid copepod has been described as a eurythermal, euryhaline, and omnivorous genera. It usually constitutes a major fraction of the total number of organisms found in the zooplankton community.

Oithona was fairly abundant in Massachusetts Bay during most of the year, unlike the other two transect sections. Vernal increase began in early May across the transect. Two strong pulses (July and September) occurred in Massachusetts Bay, while a single peak in the other two sections occurred in late July. A significantly lower seasonal peak was seen at the eastern extreme of the transect. By early November central Gulf of Maine and western Scotian Shelf abundances began to decline, not reaching winter lows until February or March of the following year. Considerably higher abundances occurred in Massachusetts Bay than the other sections.

Interannual variations of seasonality for Massachusetts Bay and the western Scotian Shelf was fairly steady from 1961-2002, except for a brief latening reaching about 30 days in 1973. After 2002 there was a steady latening until the end of the series. In the central Gulf of Maine, in the early 1960s, annual abundance peaked in early August, by 1973 in late August, and then showed an irregular earlying that by 2001 had reached early July. By the end of the series the day of maximum abundance wasn't reached until the latter part of August.

Across the transect, departures from average were negative from 1965 to 1974, from 1981-1990, and from 2002 to the end of the series. Positive anomalies occurred briefly during 1963-1964, 1978-1979, and nearly continuously from 1990-2001. Interannual abundance anomalies were quite consistent for the three transect sections through the series.

Thecosomata, (Blainville, 1821), unstaged.

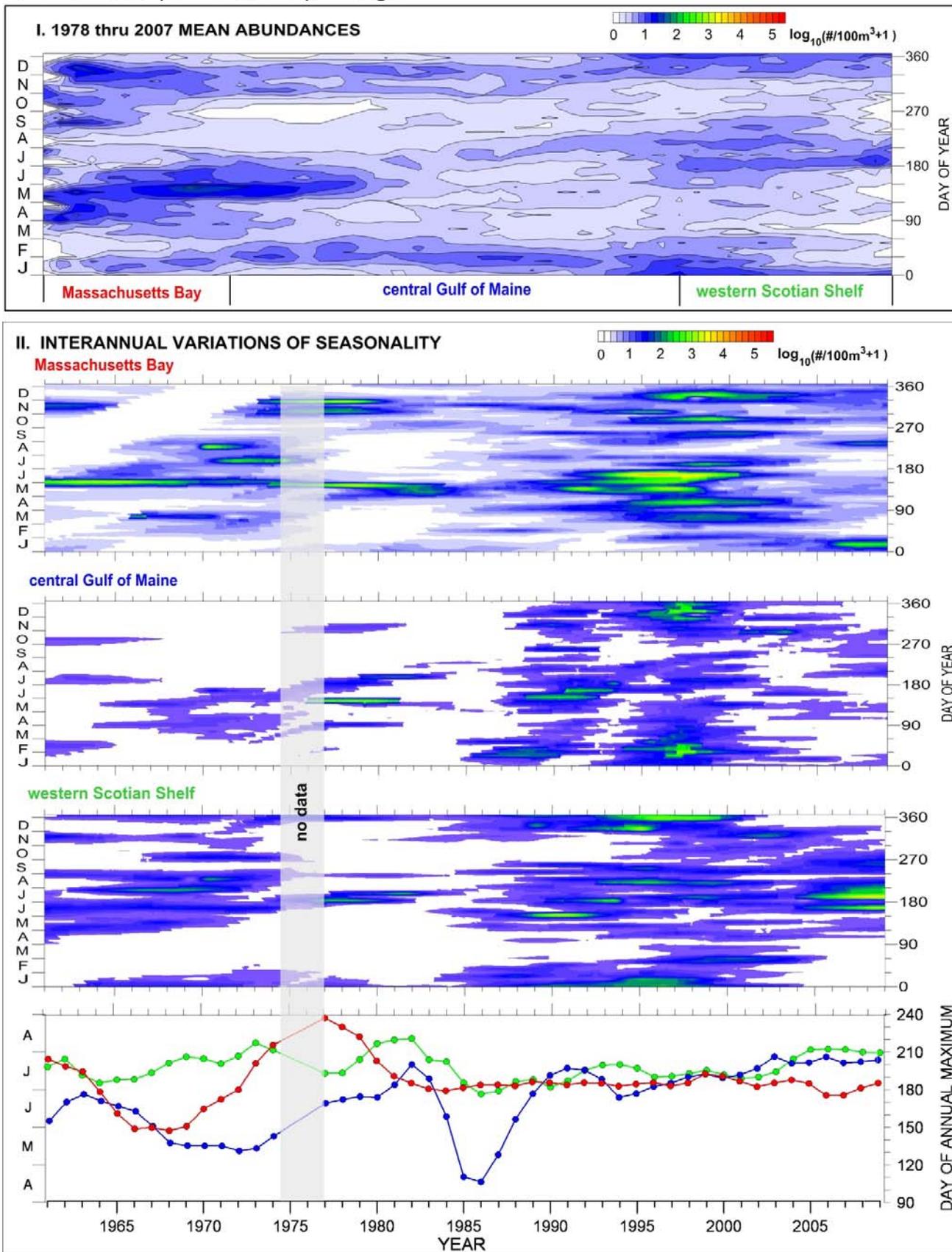


Figure 13. Thecosomata unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

Thecosomata (Blainville), 1821, unstaged

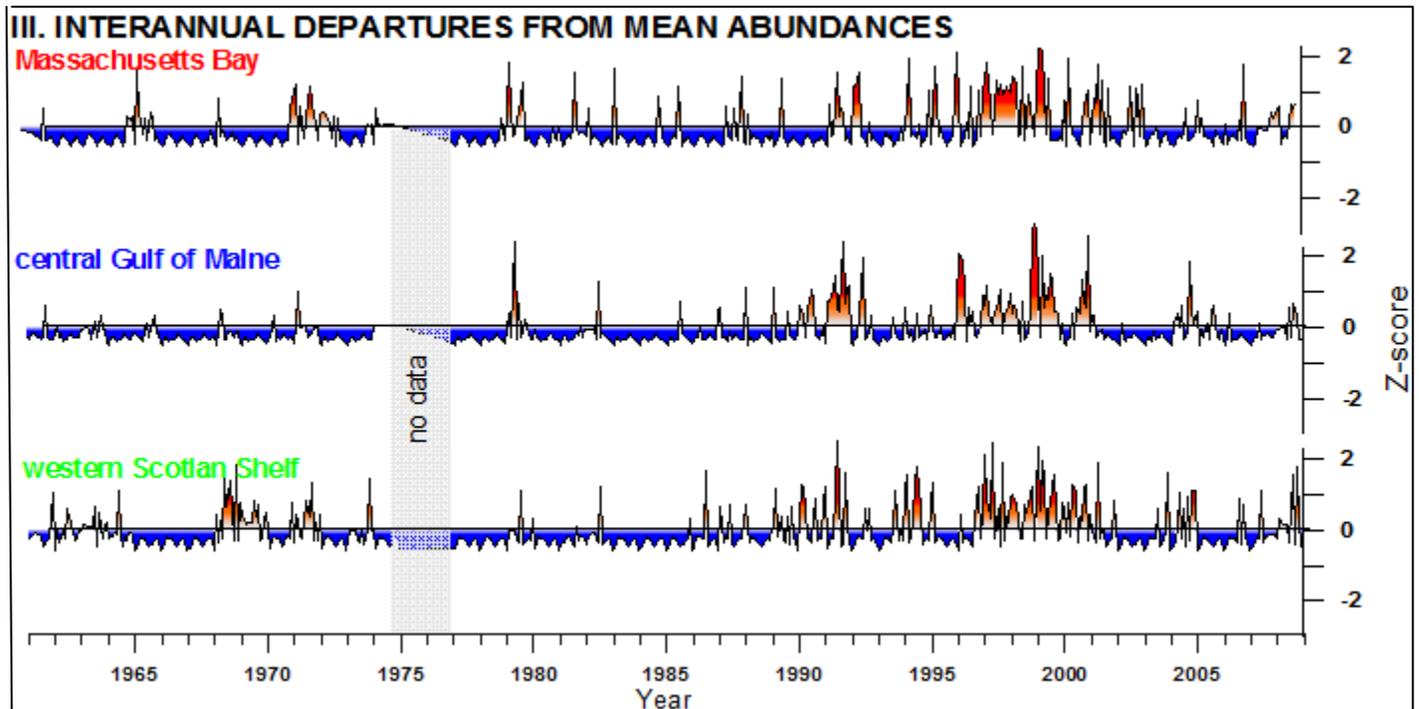


Figure 13 (cont.). Thecosomata unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The thecosomata are shelled pteropods that spend their entire life in the plankton. Many species produce a large spherical mucous web to filter-feed on phytoplankton as well as small zooplankton. The thecosomata have been targeted as critical study species regarding the impact of ocean acidification on marine life because their shell formation may be impacted by the acidifying effects of elevated atmospheric carbon dioxide levels.

Mean abundances showed them present along the entire transect from January through February. Their seasonal peak in Massachusetts Bay occurred in late May-early June, followed by a late summer low and a secondary high from September through December. On the western Scotian Shelf, abundance peaked from late June to mid-July. Low values for much of the central Gulf of Maine existed until October and November.

Seasonal peaks prior to the mid-1980s fluctuated by more than 30 days in all three sections of the transect. Except for the mid-1980s dramatic earlying in the central Gulf of Maine, timing of peaks remained much more stable until 2004, after which they occurred somewhat earlier over Massachusetts Bay and somewhat later over central Gulf of Maine and the western Scotian Shelf.

Negative anomalies dominated all three sections prior to 1990, with notable exceptions of above average conditions in the late 1960s to early 1970s on the western Scotian Shelf, and the early 1970s over Massachusetts Bay. Positive departures dominated all three sections from 1990-2001, followed by mixed phase conditions to the end of the series.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis should be put on the persistence of anomalies than on their absolute values.

Temora longicornis, (O.F. Muller, 1785), copepodite stages 4-6.

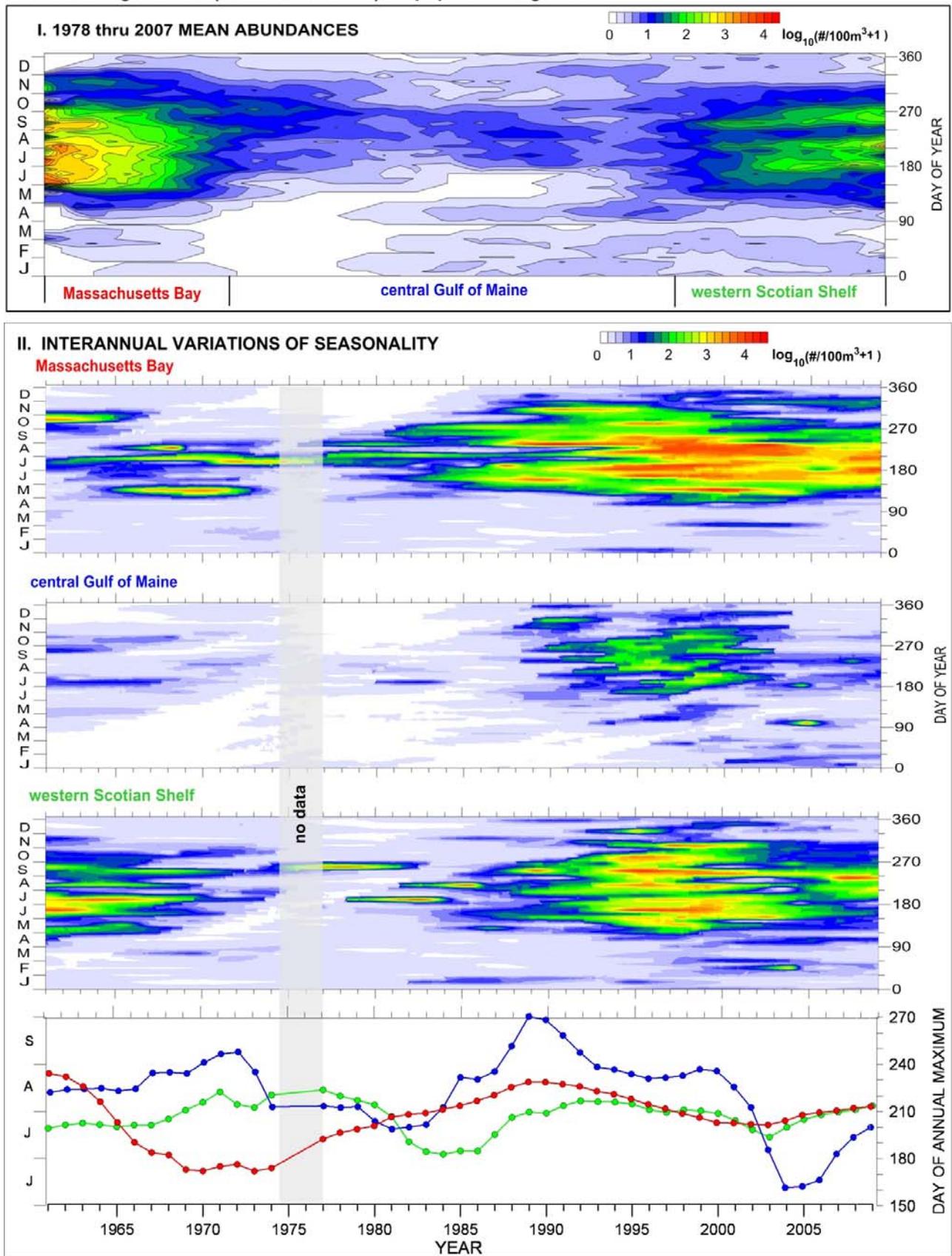


Figure 14 *Temora longicornis* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Temora longicornis, (O.F. Muller, 1785), copepodite stages 4-6

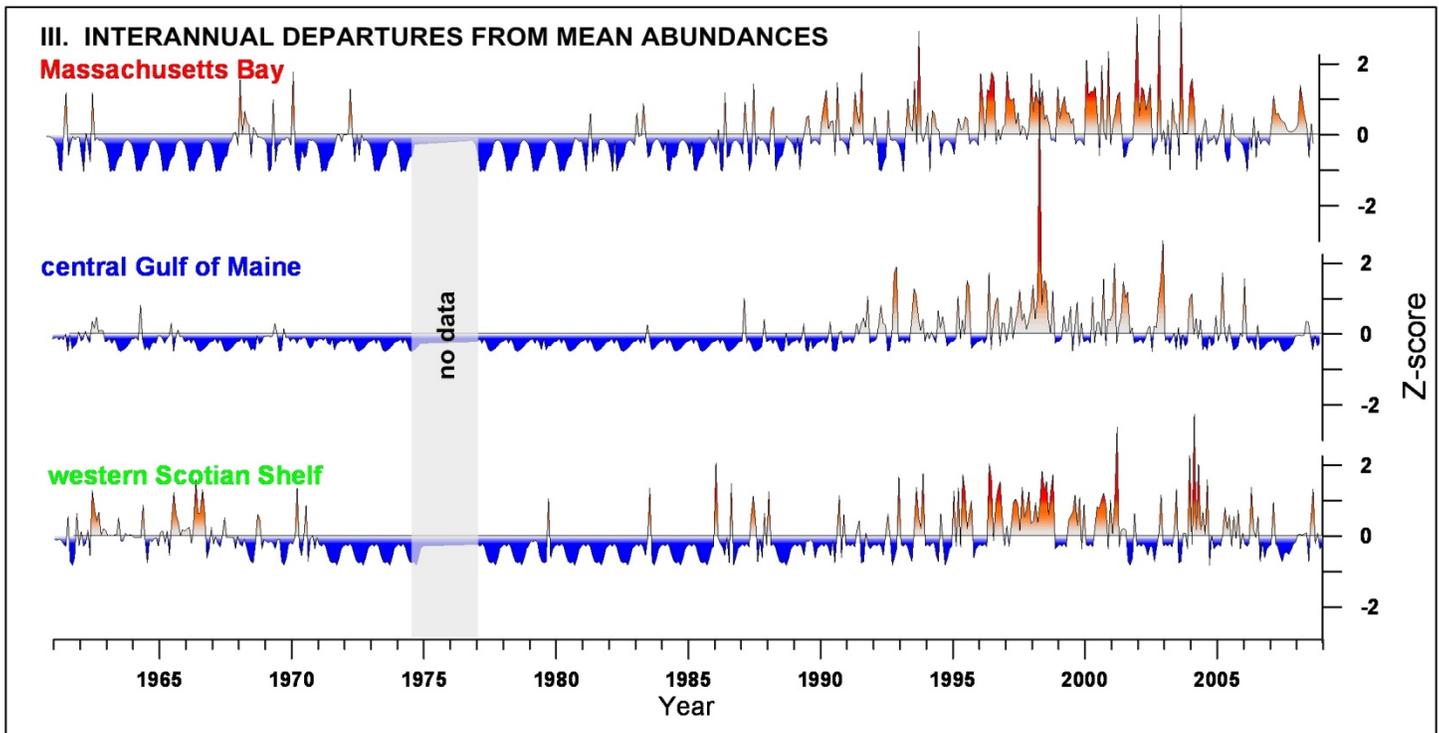


Figure 14 (cont.). *Temora longicornis* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The calanoid copepod *Temora longicornis* is usually a common component of the zooplankton assemblage that resides in coastal waters of the northern hemisphere. It is omnivorous, feeding on phytoplankton as well as on ciliates and other zooplankton. Since it has high metabolic requirements and low energy reserves, its grazing impact can be substantial on the standing stock of selected prey items. During the spring, this species can dominate copepod biomass and remove up to 50% of the daily primary production.

Except for low values in the summer, abundances in the central Gulf of Maine were zero to near zero. On the two extremities of the transect, vernal increases began in mid-April, peaked from early June to early August, and again from late August to early October, over both Massachusetts Bay and the western Scotian Shelf. Abundances reached levels several orders of magnitude greater over inner Massachusetts Bay than over the western Scotian Shelf. By December abundances had declined to near zero across the transect.

Seasonal peak in Massachusetts Bay occurred in late August followed by a steady earlying to late June by 1969, and lasting until 1974. Then began a long, but steady latening reaching mid-August in 1990. Following this, peaks occurred earlier, reaching mid-July by 2000, and then remained steady till the end of the series. Western Scotian Shelf peaks varied inversely until about 1985 when their pattern began to match that in Massachusetts Bay. Changes in seasonal timing for relatively low abundance taxa are sometimes overshadowed by the large changes in abundance. Also the selection of the base period is important.

Except for positive anomalies on the western Scotian Shelf prior to 1967, and several months in Massachusetts Bay in the late 1960s, departure were below 1978-2007 means till 1990. Thereafter, positive anomalies predominated over all three transect sections.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis should be put on the persistence of anomalies than on their absolute values.

Copepoda, Milne-Edwards, 1840, nauplius.

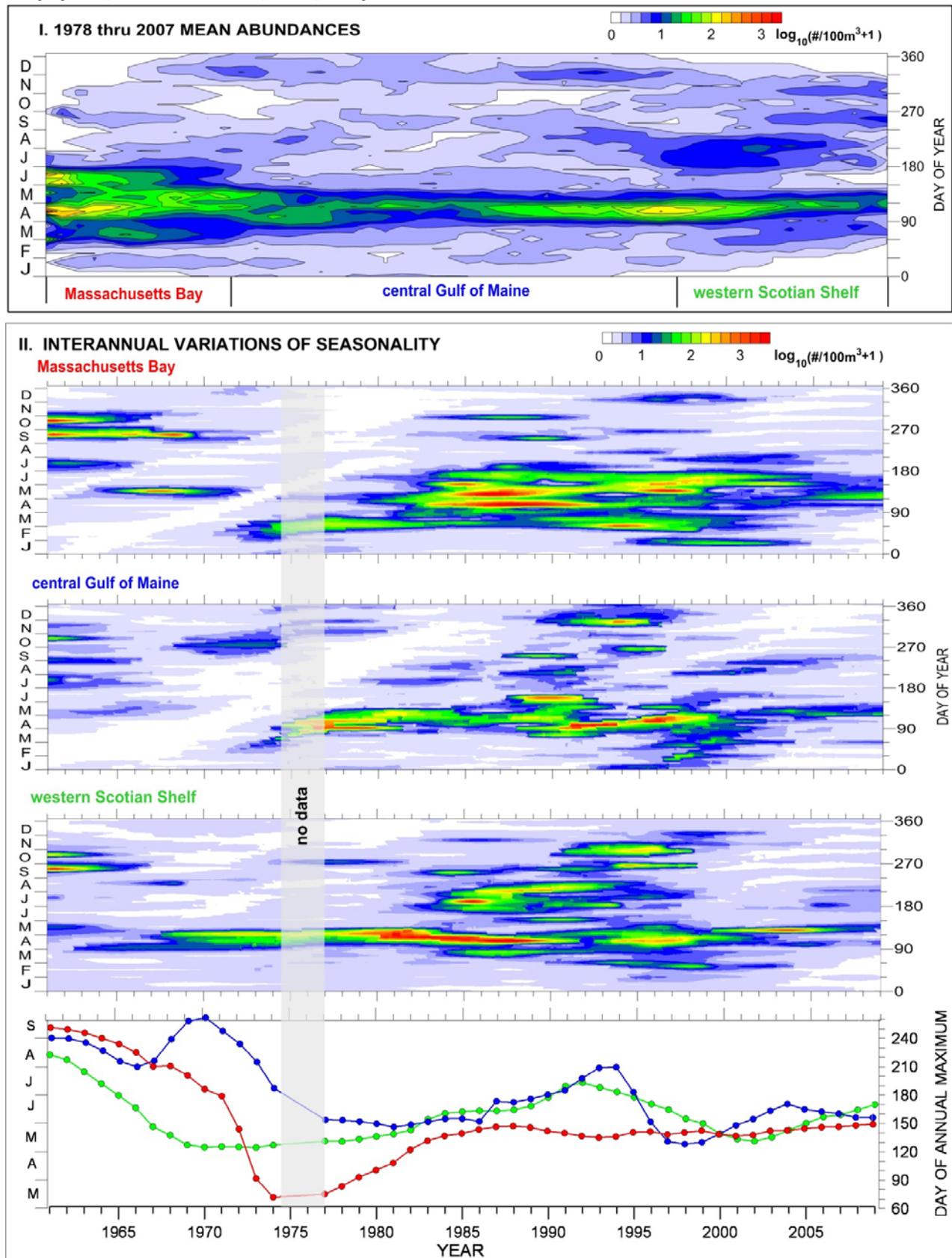


Figure 15. Copepoda nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

Copepoda, Milne Edwards, 1840, nauplius

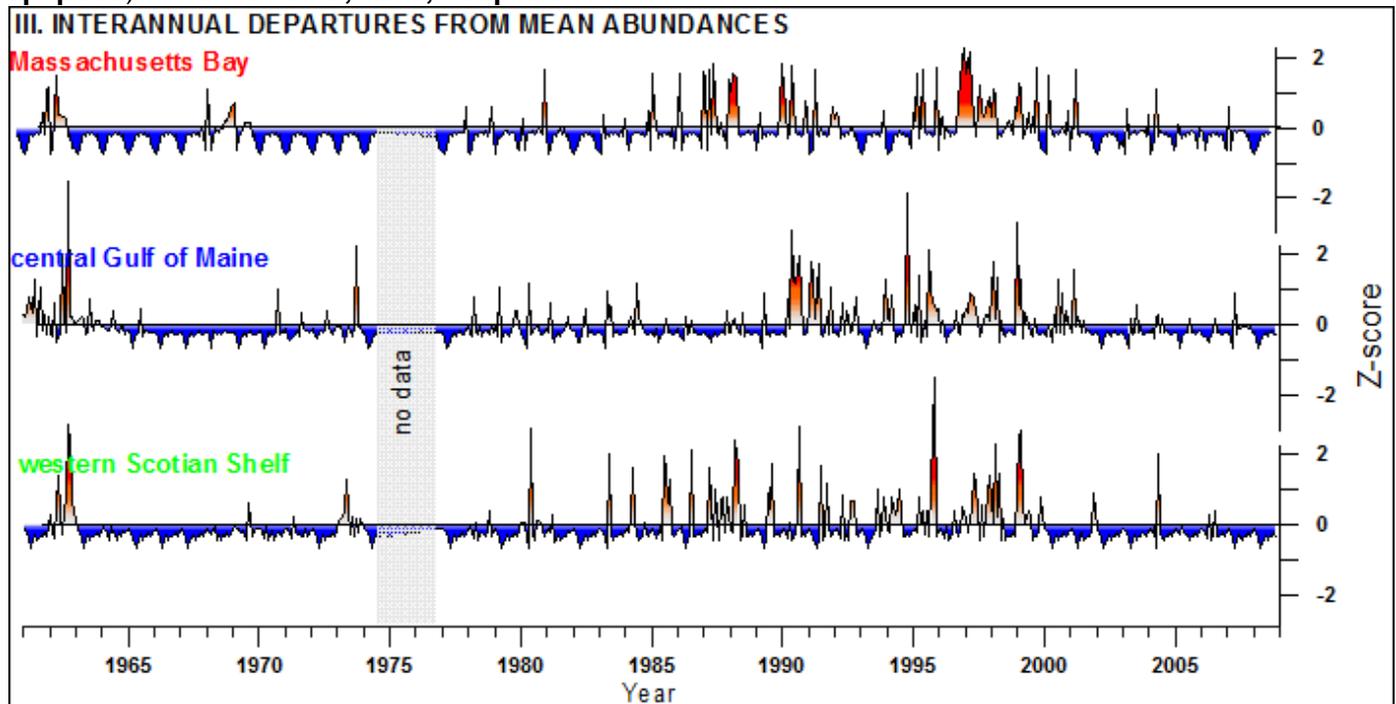


Figure 15 (cont.). Copepoda nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Copepods emerge from an egg as nauplii and have six progressively larger, free-swimming naupliar stages. They represent an important trophic link between the microbial and classical food webs. The importance of copepod nauplii as the natural first food of larval fish in the sea has been widely reported.

Mean conditions for copepod nauplii showed low levels across the transect from January until early March in Massachusetts Bay and on the western Scotian Shelf, and, until late March, over the central Gulf of Maine. Peak abundances occurred in mid-April, with highest values showing in western Massachusetts Bay and at the western edge of the western Scotian Shelf. A secondary peak in inner Massachusetts Bay occurred in early June, after which abundances returned to low levels. Higher abundances persisted on the western Scotian Shelf from July to mid-August, and in patchy time-space areas through November.

Seasonal patterns prior to 1974 in Massachusetts Bay and the central Gulf of Maine departed significantly from the base period means. This is also shown in the day of annual maximum plots. Despite attempts to minimize bias resulting from sampling coverage, these early series patterns should be used with caution. Variation of seasonality after 1977 remained relatively static.

Significant positive anomalies occurred in 1962 in all three transect sections. Otherwise, negative monthly anomalies dominated the series in Massachusetts Bay until the mid-1980s, in the central Gulf of Maine until the early 1990s, and on the western Scotian Shelf until about 1983. Positive departures prevailed in Massachusetts Bay from the mid-1980s to the early 1990s, and again from 1995 to 2001. Above average conditions occurred in the central Gulf of Maine from 1990 to 2001 and on the western Scotian Shelf from 1983 to 2000. Thereafter, all three sections were below average.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis

Figure 15 (cont.).

Acartia, Dana, 1846, copepodite stages 2-6.

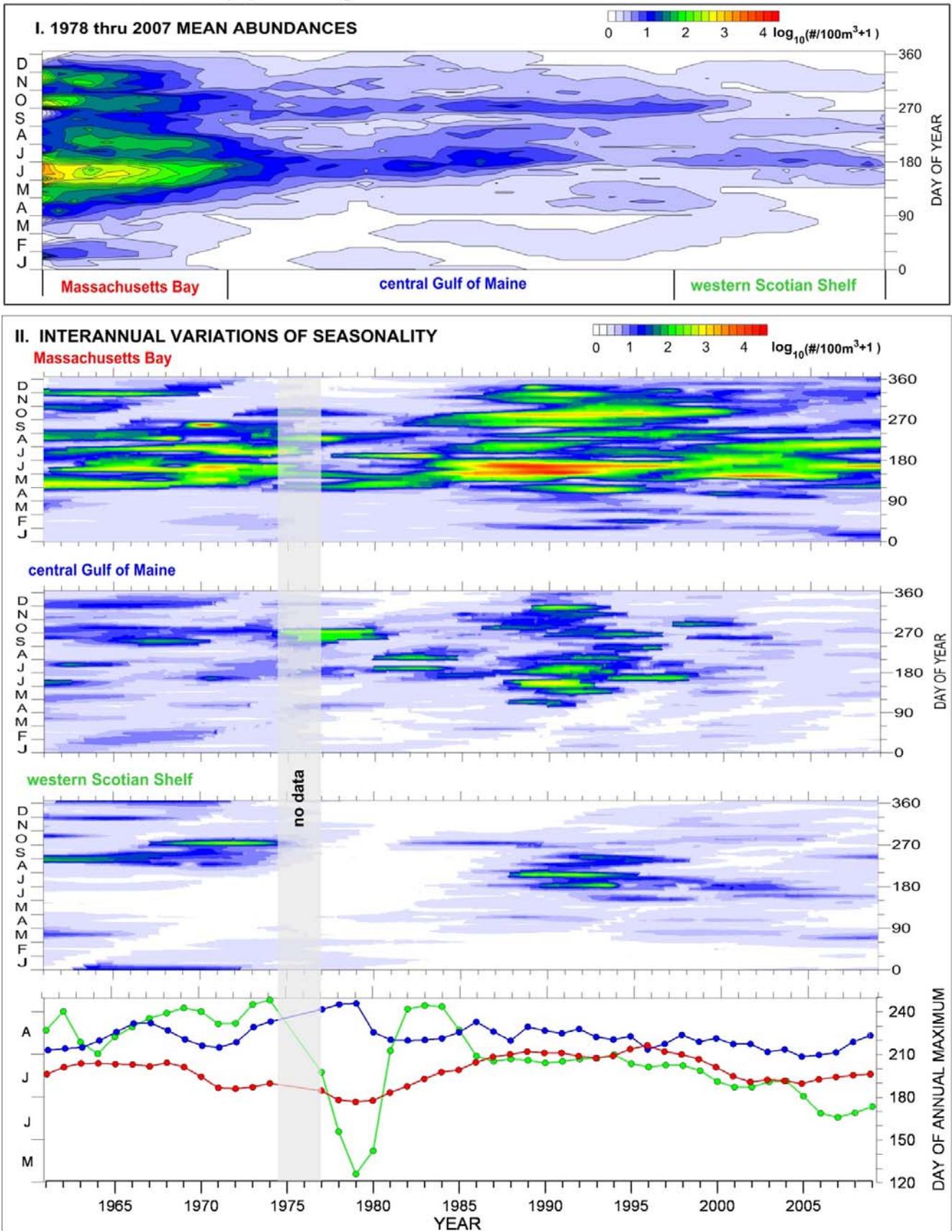


Figure 16. *Acartia* c.2-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Acartia, Dana, 1846, copepodite stages 2-6

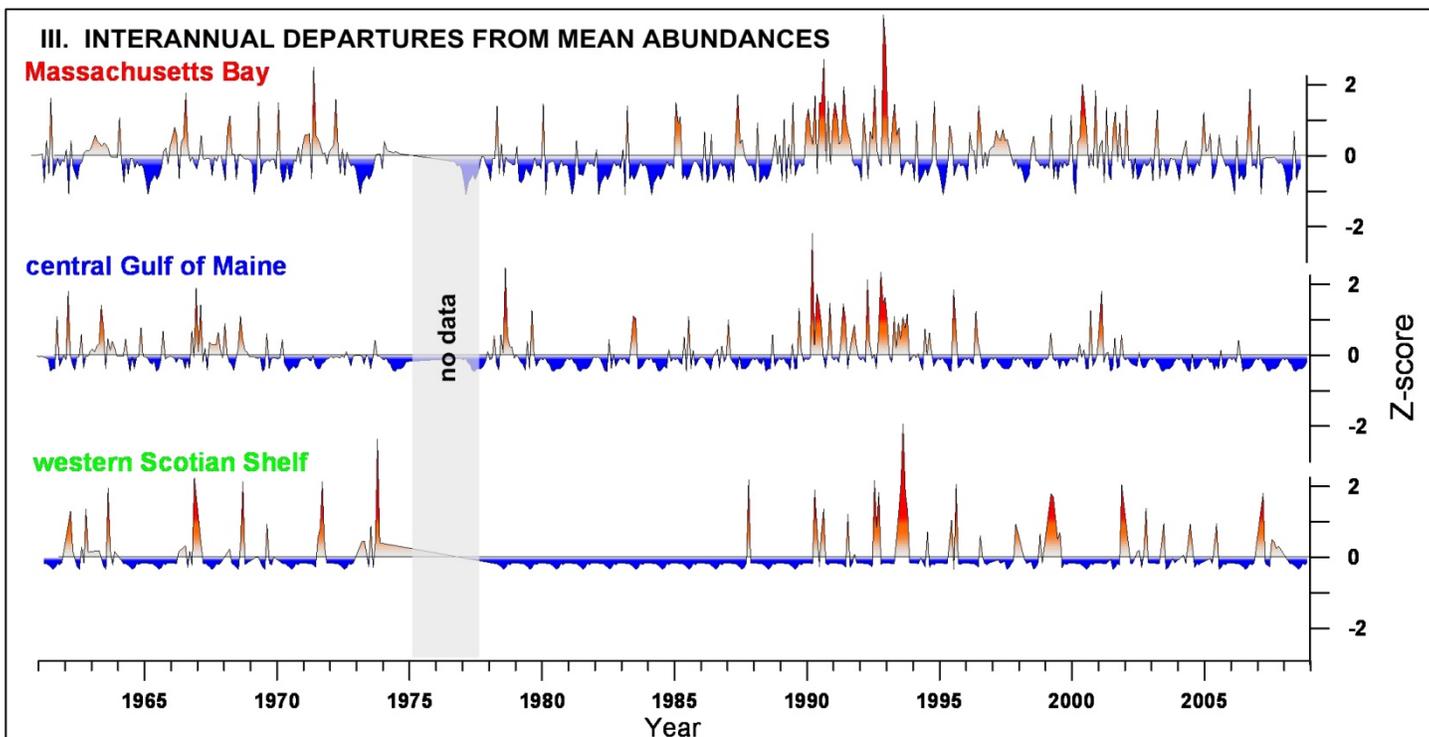


Figure 16 (cont.). *Acartia* c.2-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Acartia can dominate zooplankton assemblages in the estuaries and coastal waters of the Northwest Atlantic. Their ability to thrive and propagate in reduced salinities permits exploitation of inshore environments denied to potential competitors. *Acartia* feed primarily on phytoplankton, but also consumes ciliates, rotifers, and their own eggs and nauplii. Many species produce resting eggs that sink to the bottom and allow the species to survive through unfavorable environmental periods.

Mean conditions showed only moderate abundances east of Massachusetts Bay. Except for the short pulse in late January, *Acartia* increased above winter conditions in March, reaching a peak in June when its abundance could be seen along the entire transect. This was followed by a decline, and then a second peak in early October, again in evidences across most of the transect. Values remained high in Massachusetts Bay until early December. Throughout the year the highest abundances occurred very near the western-most end of the transect.

Seasonal timing varied slightly through the series, with a possible slight earlying trend for the western Scotian Shelf. The precipitous drop in the “day of annual maximum” curve, centered at 1979 is interesting since it is not an isolated pattern change, but is during a period of very low abundance.

Mixed-phase anomalies dominated the three section before 1975. From the late-1970s to late-1980s negative departure prevailed. Above average conditions in the two western sections were the rule from 1990-1995, after which a more mixed-phase pattern returned.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis should be put on the persistence of anomalies than on their absolute values.

Metridia, Boeck, 1865, copepodite stages 1-4.

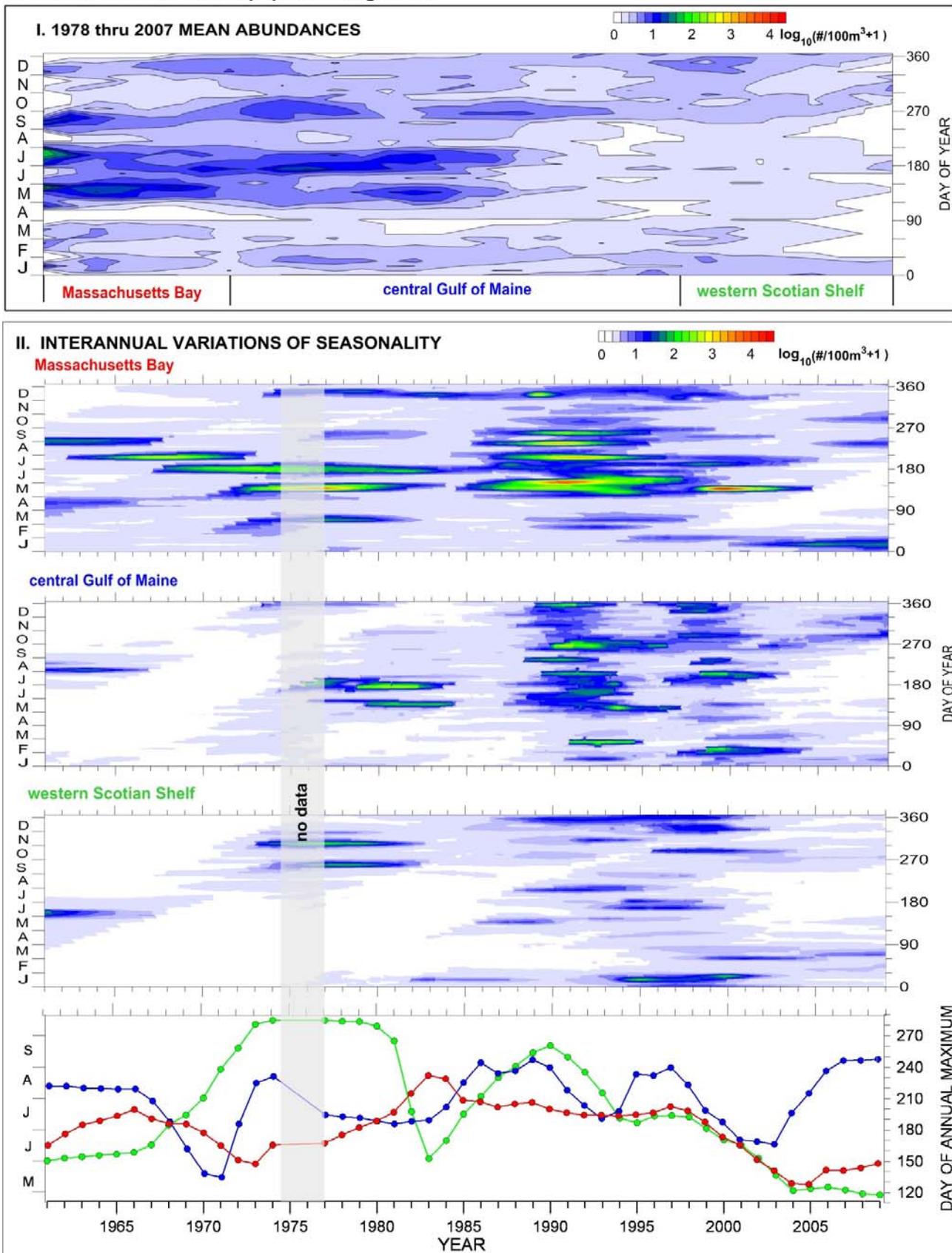


Figure 17. *Metridia* c.1-4 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Metridia, Boeck, 1865, copepodite stages 1-4

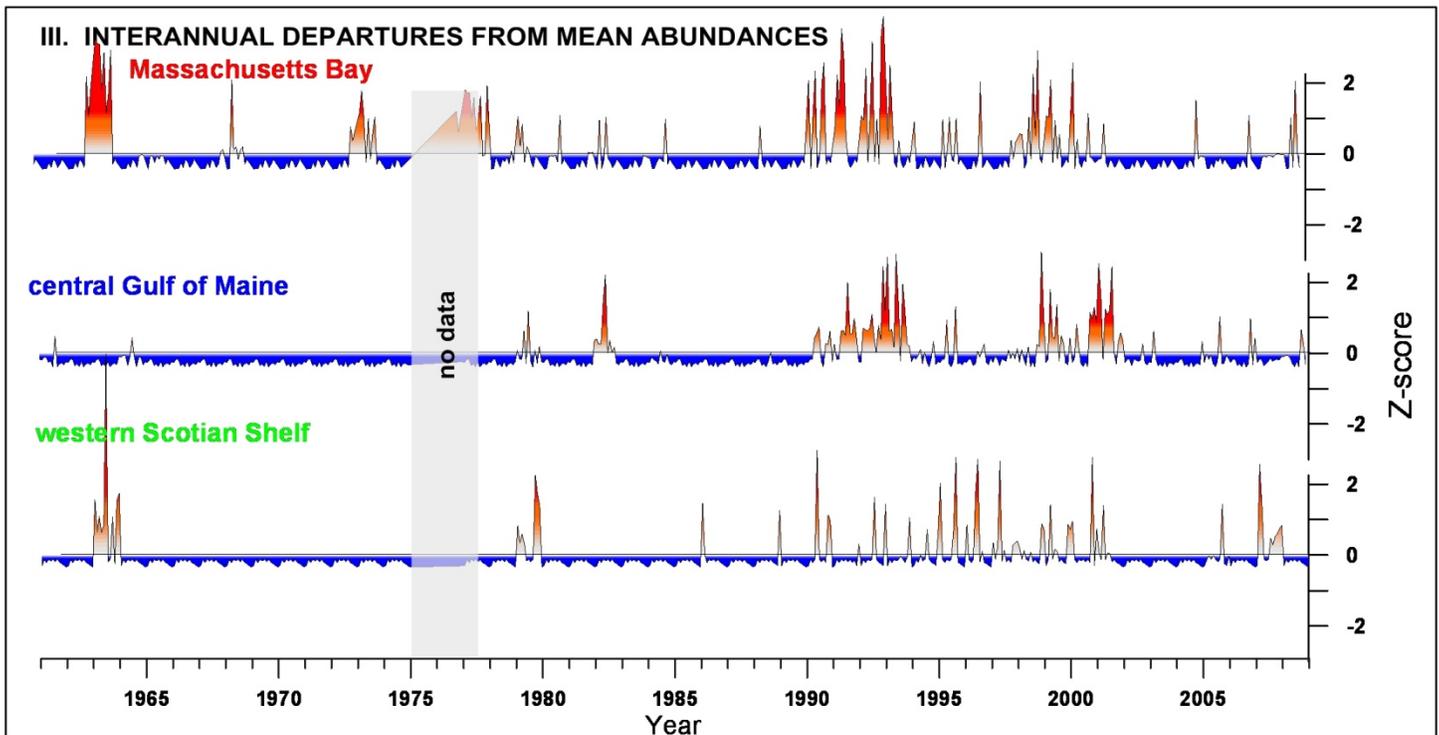


Figure 17 (cont.). *Metridia* c.1-4 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The genus *Metridia* has both coastal and oceanic representatives in the temperate and boreal waters of the North Atlantic. Specimens from the Gulf of Maine CPR survey could be either *M. lucens* or *M. longa*, but given the much higher abundance of the former in the Gulf of Maine, it seems likely that most of these early copepodites are *M. lucens*. They are strong vertical migrators and have been found to spend longer periods of time near the surface than the older stages.

Mean conditions showed the taxon present along most of the transect, with zero abundance common much of the time on the eastern end. Abundance pulses occurred over the western half of the transect with peaks in May, July, September, and December. This relatively large discontinuity of production may have been a result of the mixed species involved.

Changes in the seasonal pattern were most dramatic on the western Scotian Shelf, where abundances were lowest. Earlier peaking was seen in Massachusetts Bay in the early 1970s and after 2000, with slight latening after 2005. A similar pattern, with differing magnitude, was seen for the central Gulf of Maine.

Significant positive anomalies occurred during much of 1963 and 1973 over Massachusetts Bay, and during 1963 and 1979 over the western Scotian Shelf. The central Gulf of Maine had a lesser positive departure during 1983. Otherwise, the three sections were below average until 1990. Anomalies were positive from 1990 to 1994, and 1998 to 2002 in Massachusetts Bay and the central Gulf of Maine, followed to the end of the series by negative departures. Over the western Scotian Shelf anomalies were mixed from 1990 to 2002, negative till 2005, and mixed thereafter.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis should be put on the persistence of anomalies than on their absolute values.

Metridia lucens, Boeck, 1865, copepodite stages 5-6.

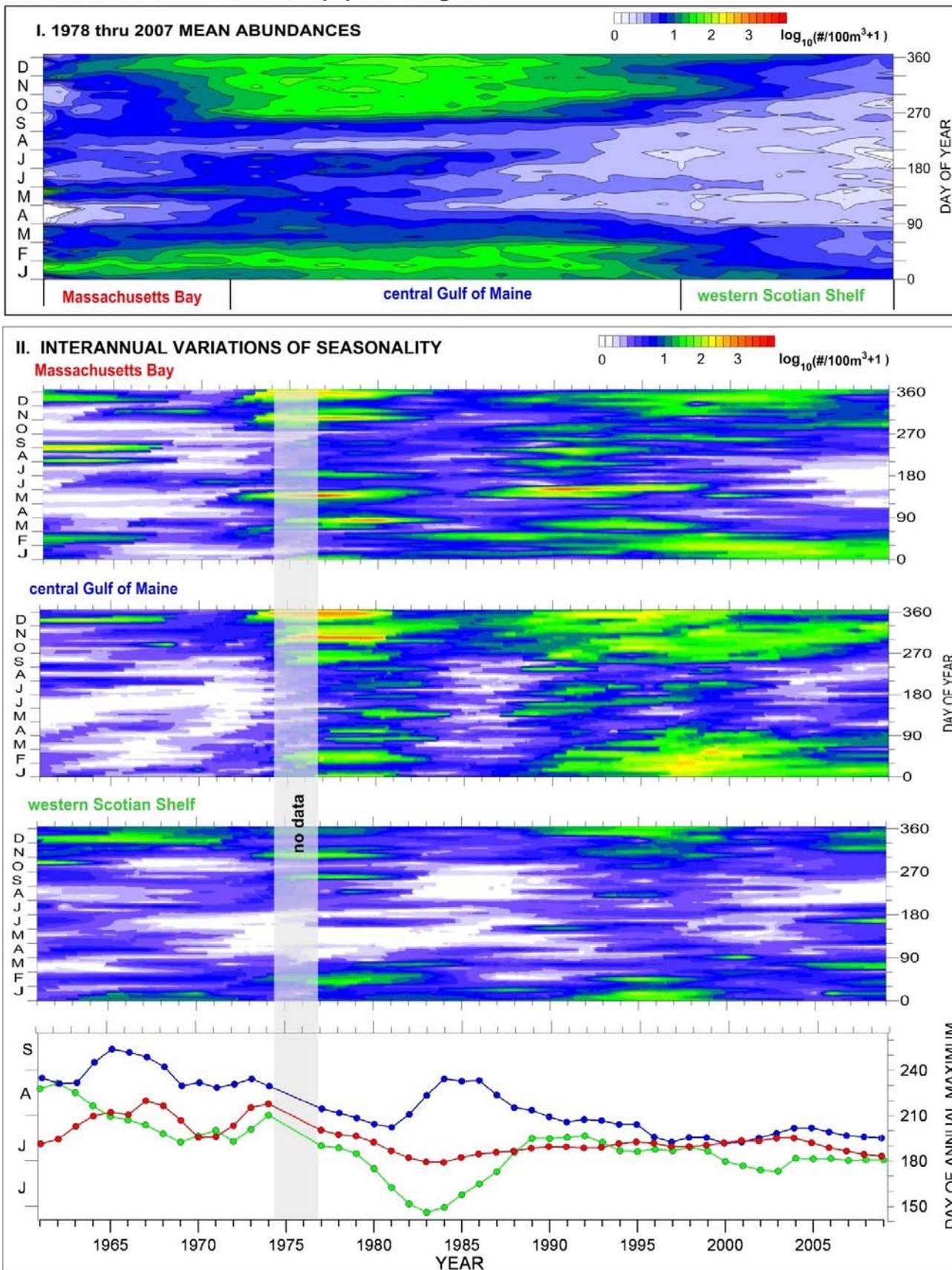


Figure 18. *Metridia lucens* c.5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

***Metridia lucens*, Boeck, 1865, copepodite stages 5-6.**

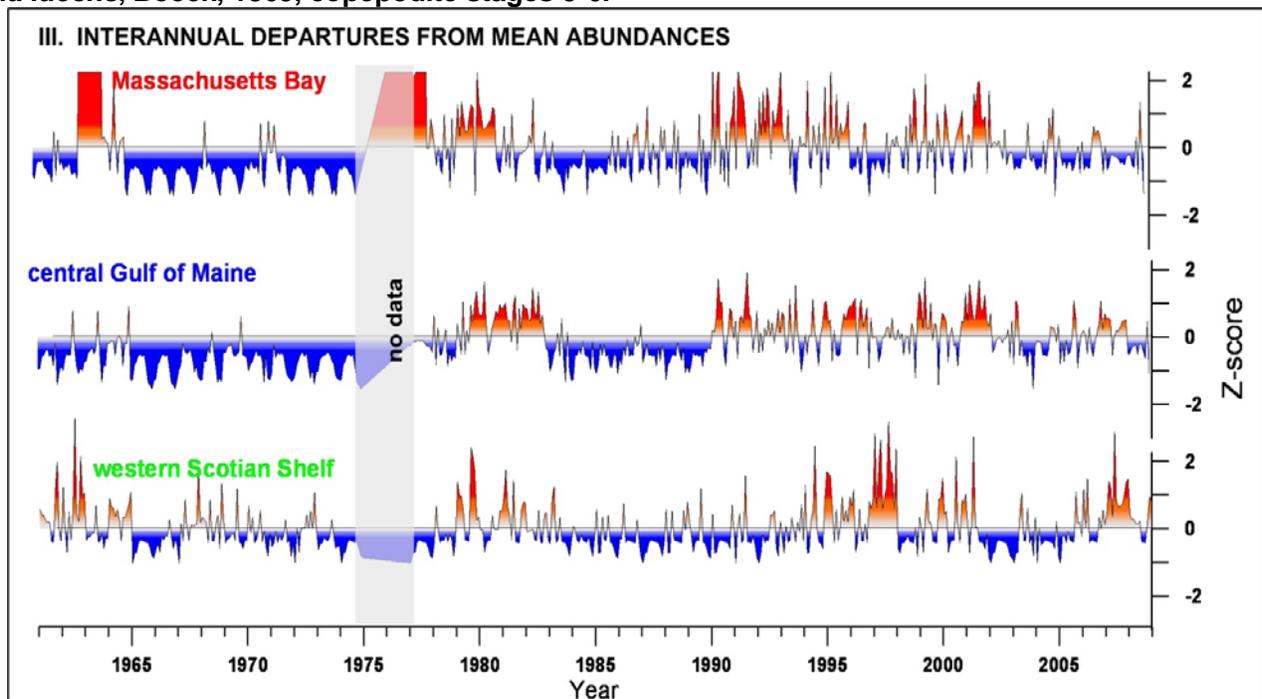


Figure 18 (cont.). *Metridia lucens* c.5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Metridia lucens is one of the larger copepod species and is distinguished by being one of the few luminescent ones found in the Gulf of Maine. The adults are strong vertical migrators, demonstrating a strong bimodal day-night distribution. As a result, they are primarily caught by the CPR at night when they concentrate in the surface waters to feed and/or avoid predators. *Metridia lucens* are omnivores that have been observed to be voracious predators on small zooplankton.

On average, they occurred through most of the Gulf of Maine with lower abundances over the western Scotian Shelf. Higher values occurred in January and February in Massachusetts Bay and the central Gulf of Maine, with a reduction until late September, when the major seasonal pulse occurred over the central Gulf of Maine and extended into the following year, spreading again into Massachusetts Bay.

A general earlying of the day of annual maximum occurred during the series in all three sections of the Gulf of Maine. In Massachusetts Bay it varied from late July/early August in the mid- 1960s to early July by the end of the series. More dramatic changes occurred in the central Gulf of Maine, varying from mid- to late August in the early years to mid-July by 2009; and on the western Scotian Shelf occurring also from mid- to late August in 1961 to early July by the end of the series. A major departure from this Gulf-wide earlying trend occurred in the early to mid-1980s when the day of maximum latened by nearly a month in the central Gulf of Maine and occurred nearly a month earlier on the western Scotian Shelf.

Positive abundance anomalies in Massachusetts Bay occurred in 1964, from 1977 to 1982, 1990 to 1996, and 1999 through 2001. With the exception 10 1964, a somewhat similar pattern occurred in the central Gulf of Maine, with additional, but scattered positive departures occurring after 2005. On the western Scotian Shelf above average abundances although less consistent than those to the west, occurred during those times seen in Massachusetts Bay, but with two notable additions: scattered positive anomalies in the late 1960s to early 1970s, and more consistent positive departures after 2007. The period, 1965 to 1975 showed below average abundances in Massachusetts Bay, the central Gulf of Maine, and to a lesser extent, the western Scotian Shelf. A second prolonged period of negative abundance occurred from 1982 to 1990 in all three sections. After 2002 in Massachusetts Bay negative conditions prevailed, while in the central Gulf of Maine departures were mixed. From 2002 to 2006 on the western Scotian Shelf negative anomalies dominated.

Podon, Lilljeborg, 1853, unstaged.

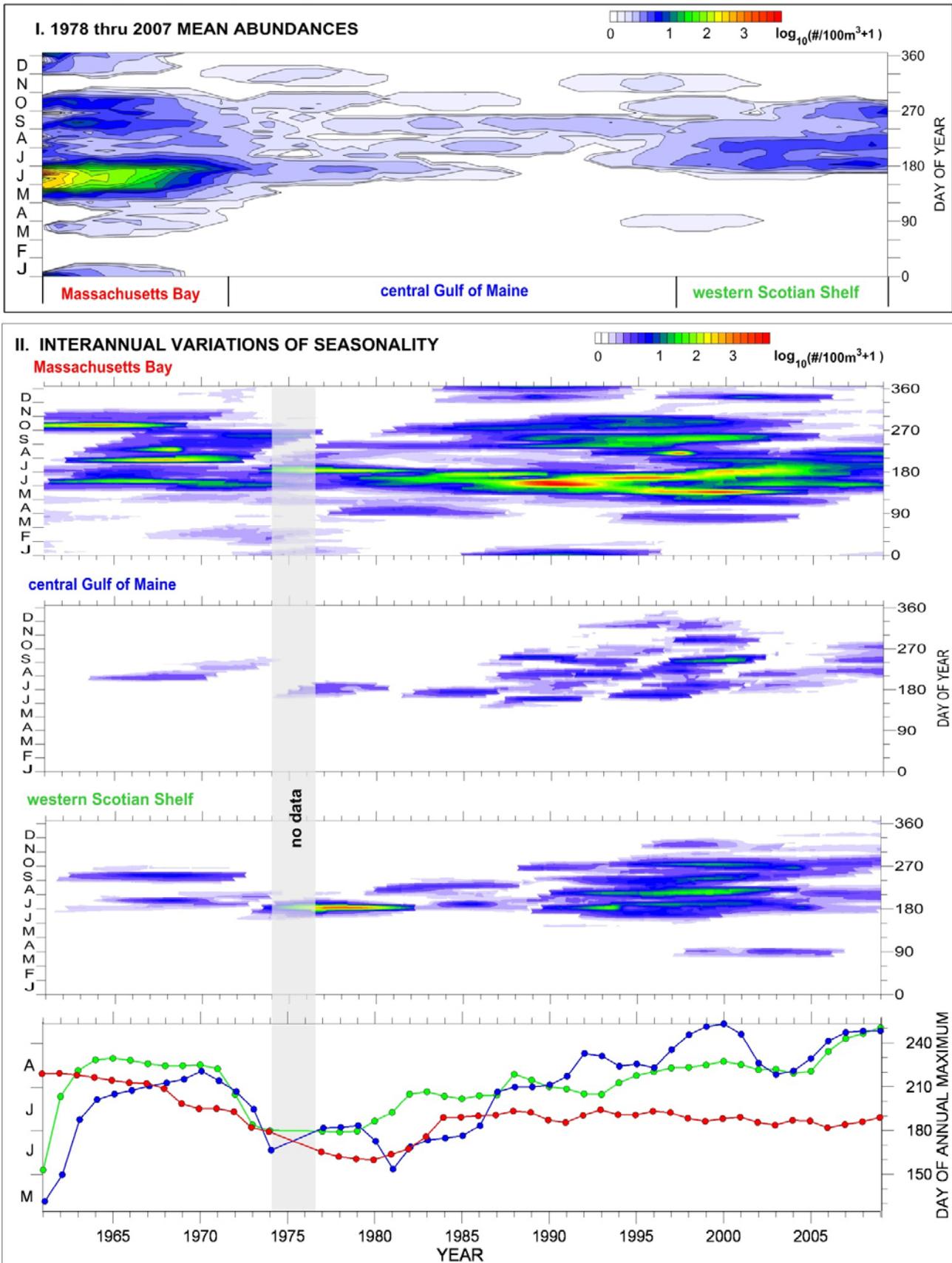


Figure 19. *Podon* unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

Podon, Lillgeborg, 1853, unstaged

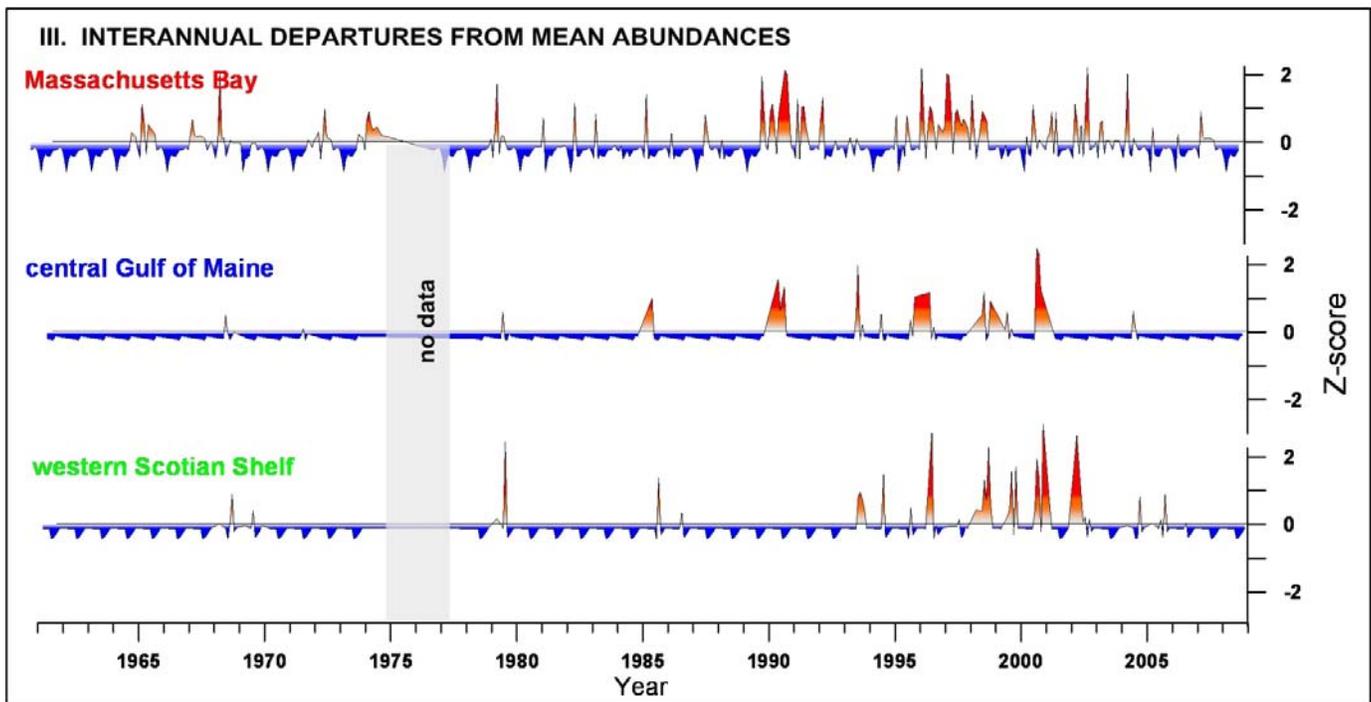


Figure 19 (cont.). *Podon* unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Cladocerans of the genus *Podon* are common in coastal waters throughout the world's ocean. These "water fleas" are distinguished by large, dark eyes on a head that is clearly separated from a round carapace that surrounds the body. Though their feeding ecology has not been well studied, their well developed eyes suggest they are raptorial feeders that perceive and select individual prey. Cladocerans reproduce by parthenogenesis and have short generation times that can lead to fast population blooms when environmental factors are favorable.

Except at times of annual peak abundance *Podon* was confined to the Massachusetts Bay and western Scotian Shelf sections of the transect. Spring increase began in the former in May, peaked in June, remained high until the end of October (including a secondary peak in late September), then resurged in December and early January. Over the western Scotian Shelf the spring increase started one and one half months later than in Massachusetts Bay, dropped off sharply in mid-October, and did not reach the abundance levels seen in Massachusetts Bay.

Seasonal variation in Massachusetts Bay showed a departure from mean conditions from 1977 through 1983 where an earlier, but isolated peak appeared and the mean peak largely disappeared after mid-July. The shortened, peak period was seen again after 2004. Over the western Scotian Shelf similar patterns of peak period duration were seen.

Prior to 1990 in Massachusetts Bay, above average abundances, of several months duration occurred in 1965, 1967, and 1974. More prolonged positive departure occurred from 1990-1993 and 1996-1999. Otherwise anomalies were generally negative. Several periods in central Gulf of Maine after 1985 had abundances higher than the usual low levels. Prior to 1993 the western Scotian Shelf was mostly below the base period, an exception being in 1979. From 1993-2003 *Podon*, like most of the other dominant zooplankton exhibited positive anomalies.

Note: Standardized anomaly values for taxa with large numbers of observed abundances equal to, or near zero, raises the question of whether near normal data distributions are obtained via the logarithmic transformations. Thus, more emphasis should be put on the persistence of anomalies than on their absolute values.

Sessilia, Lamarck, 1818, nauplius.

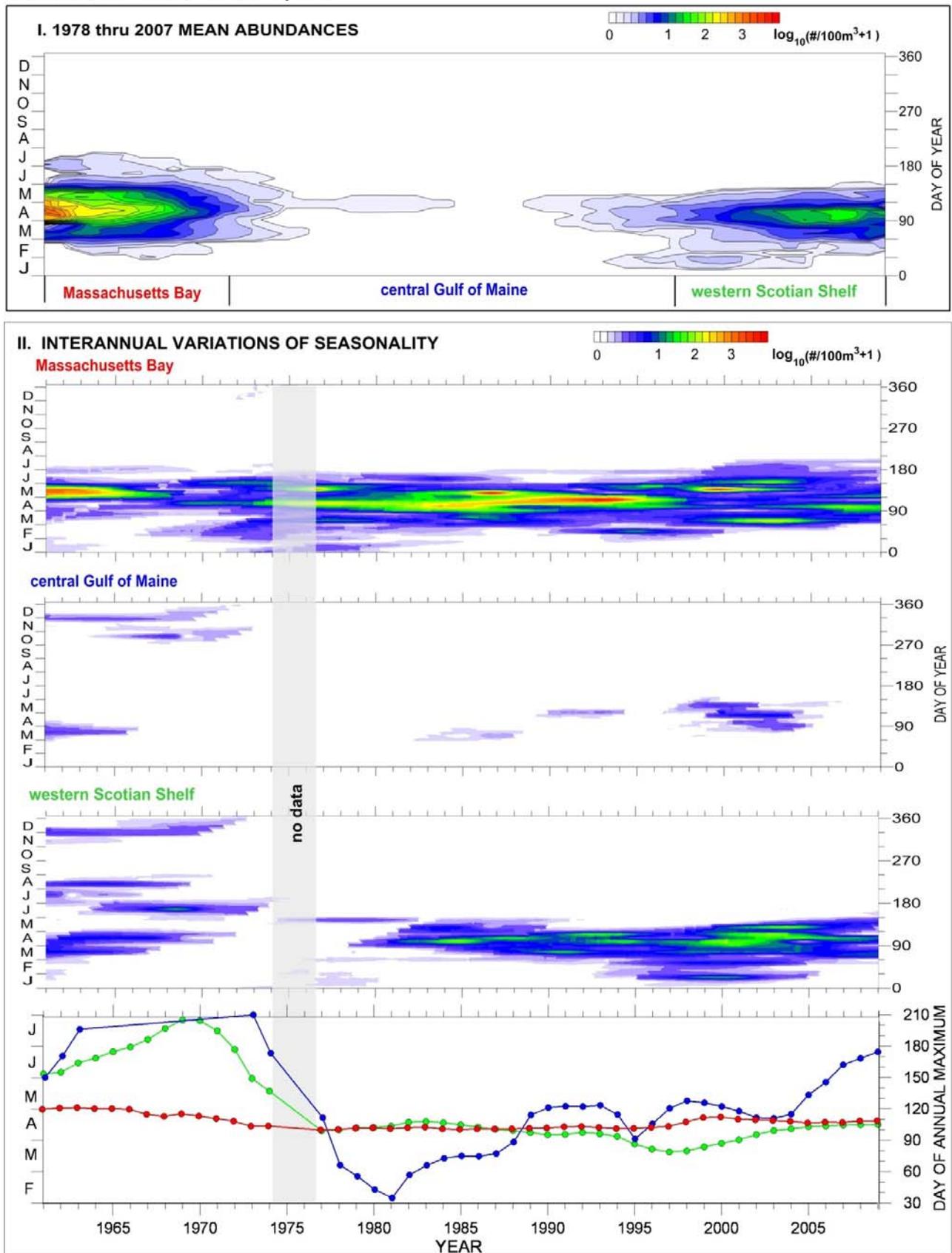


Figure 20. Sessilia nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

Sessilia, Lamarck, 1818, nauplius

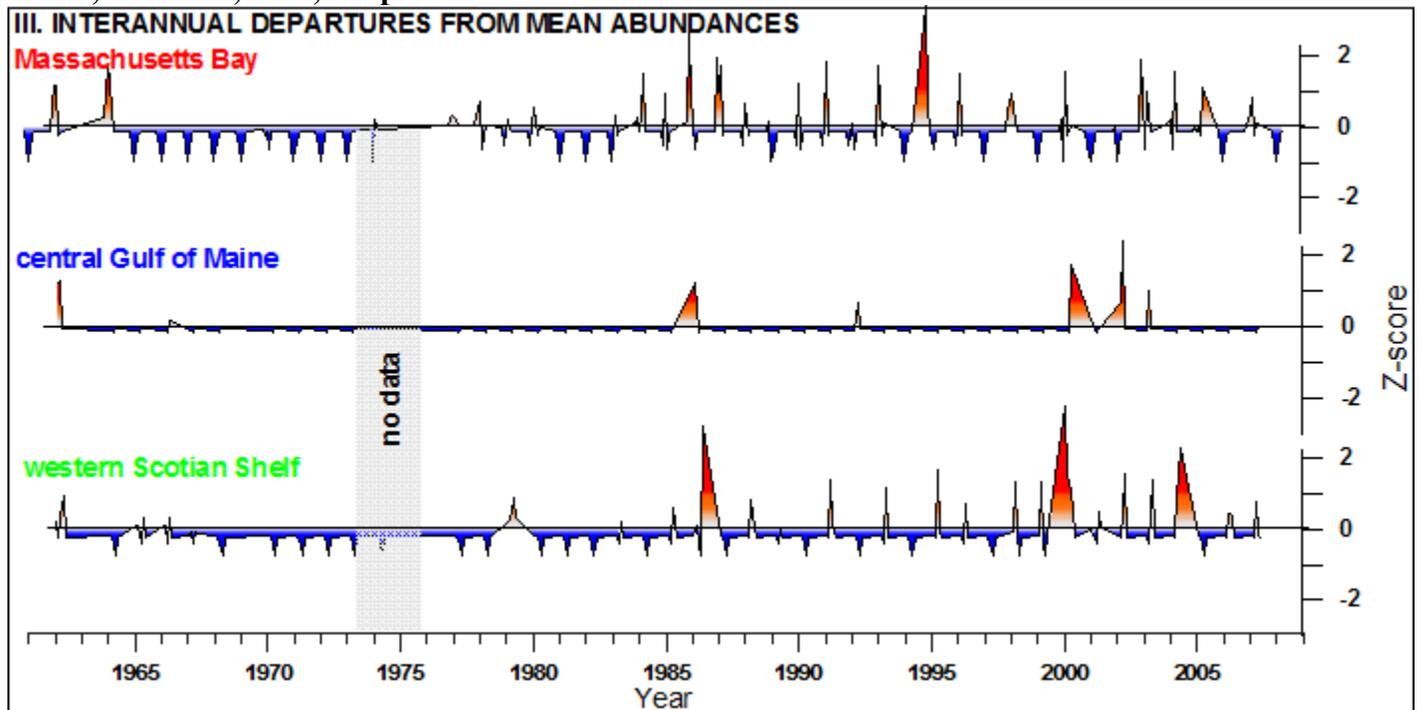


Figure 20 (cont.). Sessilia nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The adults of these nauplii are commonly known as barnacles, which is a widespread marine group that dominate rocky littoral zones. The first larval stages are planktonic, and pass through six naupliar stages before metamorphizing into the non-feeding cypris larvae. Barnacle nauplii feed on phytoplankton and microzooplankton and are important prey of fish larvae and other planktonic predators.

Mean abundances showed very distinct time-space boundaries. Presence is confined to the two shelf sections. In Massachusetts Bay the nauplii appear in late February, peak in April, and are absent after mid-July. Over the western Scotian Shelf a small patch of nauplii was seen in late January, but the bulk of the abundance appeared after mid-February, peaked in April, and was absent from the samples after May. Peak values over the western Scotian Shelf were about one order of magnitude less than those in Massachusetts Bay.

Variations of seasonality in Massachusetts Bay were quite small, as can be seen in the “day of annual maximum” graphic. On the western Scotian Shelf, prior to the early 1970s, sessilia occurred at several times through the year, ranging from March to early December. After 1980 its seasonal pattern stabilized, and with the exception of some high abundance years after 1995, resembled the mean pattern.

Positive anomalies in Massachusetts Bay occurred before 1964 and again in the mid-1980s and mid-1990s. From 1965-1985 departures were below average. Otherwise the pattern was mixed. On the western Scotian Shelf negative anomalies prevailed until nearly 2000, with positive exceptions in 1979 and 1986. Significantly positive departures occurred in 1999 and 2004. Otherwise, anomalies were mixed.

Evadne, Loven, 1836, unstaged.

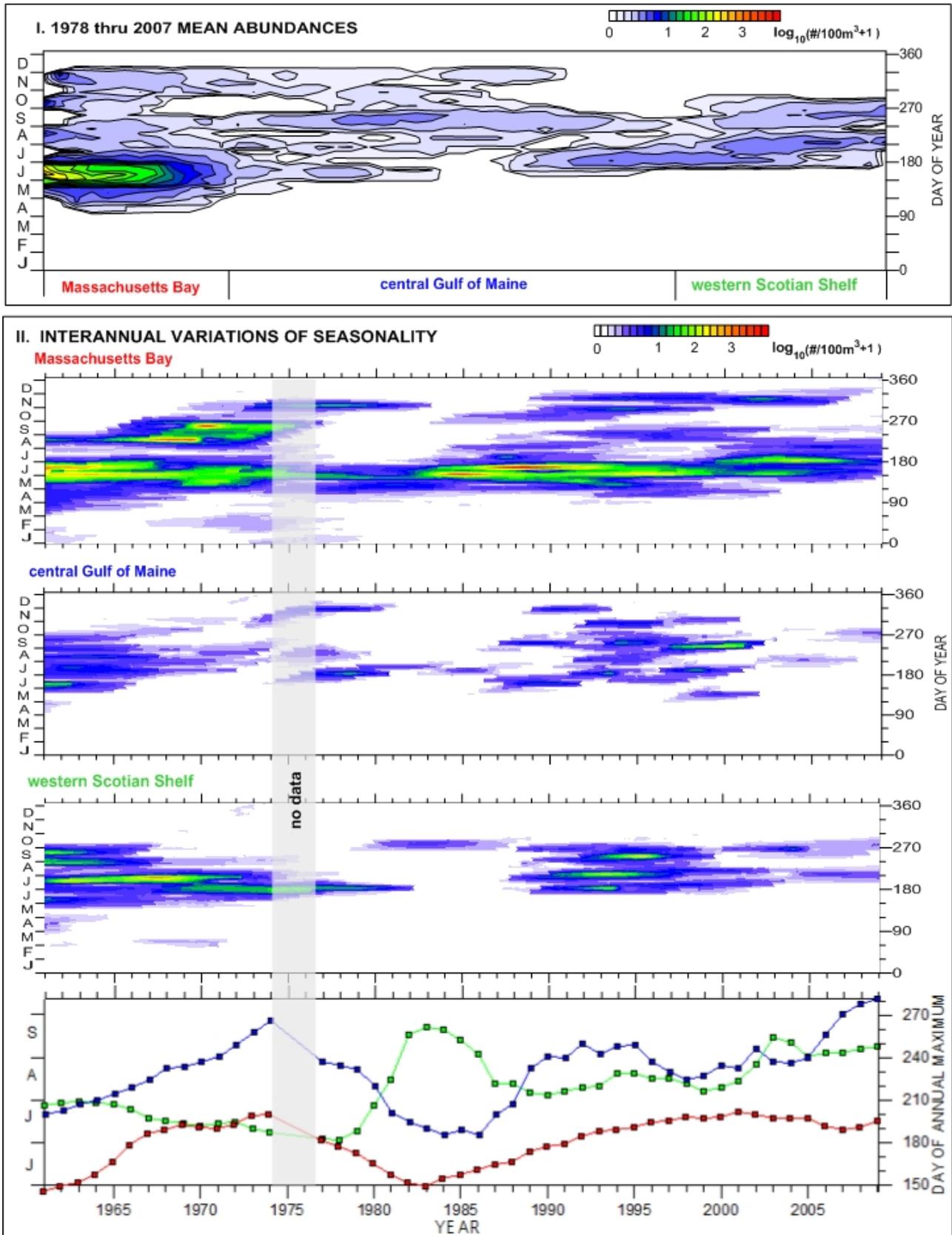


Figure 21. *Evadne* unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

Evadne, Loven, 1836, unstaged

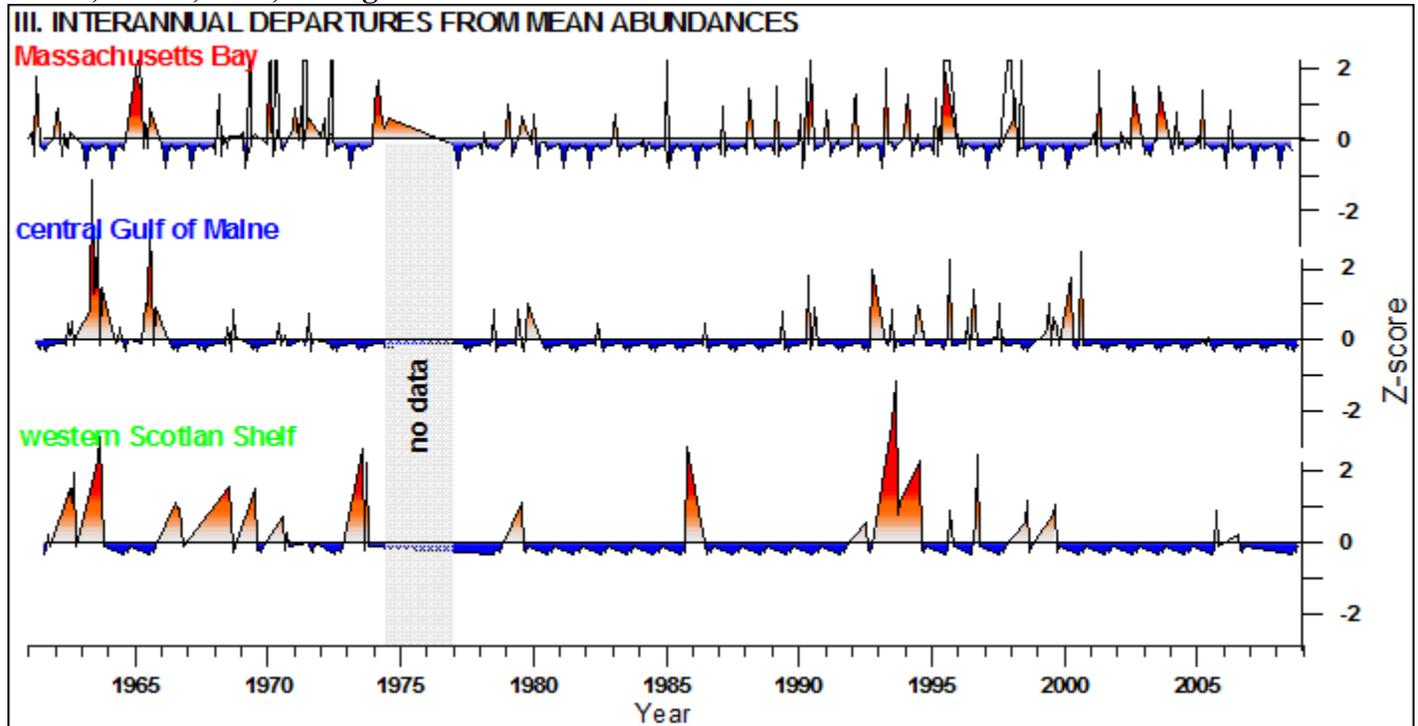


Figure 21 (cont.). *Evadne* unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

This genus of marine cladocerans is widely distributed throughout the world's oceans. It has a transparent, teardrop-shaped body and its principal mode of reproduction is parthenogenesis. Populations can bloom quickly under favorable environmental factors that are usually linked to vertical stability. It has been found in the larval diets of commercially important fish species that inhabit the Gulf of Maine.

Mean abundances were concentrated in Massachusetts Bay from late April to late August, peaking in June, followed by a secondary swarm from October through November. In the central Gulf of Maine the taxon appeared in July, connected to the western Scotian Shelf's annual pulse, and again from August through September. Over the western Scotian Shelf, moderate abundances were seen from July through mid-August, and again from September through late October. Maximum Gulf of Maine mean values occurred over inner-Massachusetts Bay.

Peak abundances in Massachusetts Bay occurred later each year from 1961 through 1974, then steadily occurred earlier until 1983. A steady latening followed until about 2001, after which the timing remained fairly constant. Prior to 1983 in the central Gulf of Maine the pattern followed that seen in Massachusetts Bay. Thereafter, to the end of the series, peak annual abundance latened by 185 days. The main features on the western Scotian Shelf were the absence of the early summer swarm in the early 1980s and the overall latening of the peak through the series.

Departures from 1978-2007 means had less continuity than some of the other taxa. One exception was the prolonged above average conditions over the western Scotian Shelf prior to 1974. The commonly seen positive anomalies for many other zooplankton taxa in the 1990s were also seen for *Evadne* in all three sections. The positive departures over the western Scotian Shelf in 1986 and approaching 1995 are especially noteworthy.

Appendicularia, unstaged.

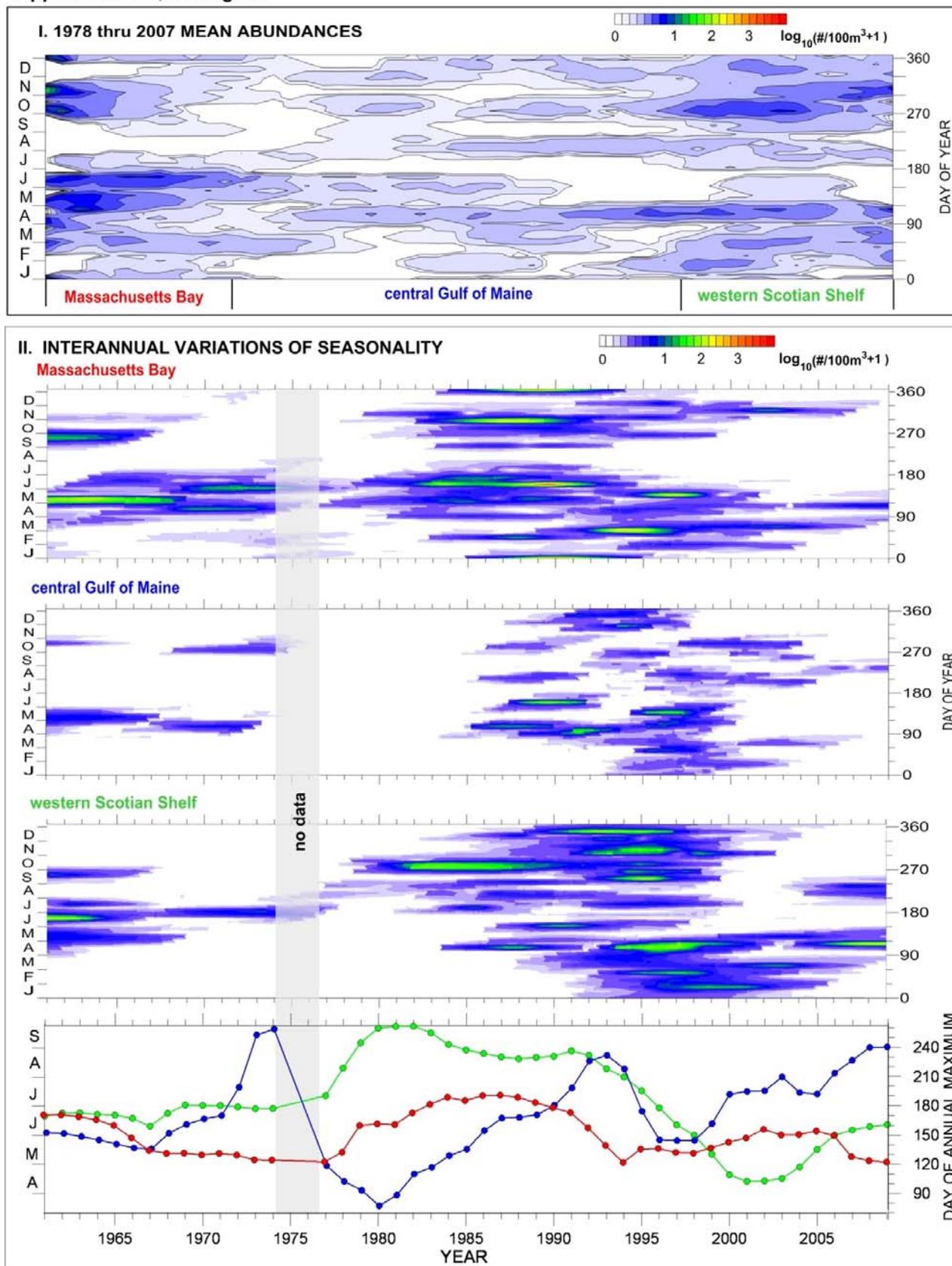


Figure 22. Appendicularia unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

Appendicularia, unstaged

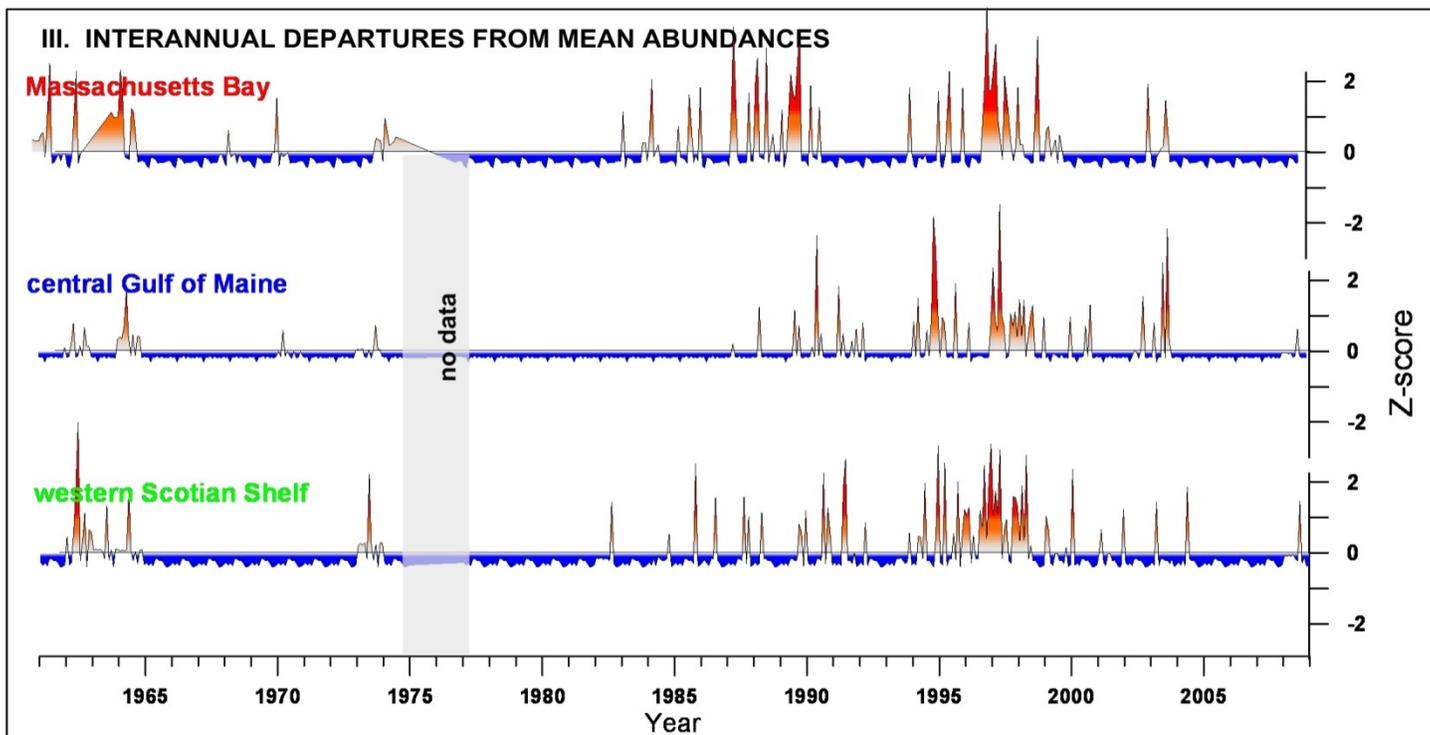


Figure 22 (cont.). Appendicularia unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Appendicularia are small, fragile, free swimming tunicates with a body consisting of a short trunk and a muscular tail. They secrete around themselves a gelatinous mass in which are incorporated elaborate structures used to filter food items. These “houses” need to be discarded and replaced several times per day because they become clogged by large particles or are simply worn down. Since these structures are rich with mucous and trapped food, they comprise a rich source of food for several pelagic and benthic organisms.

Mean values showed a patchy distribution of this taxon. Over Massachusetts Bay, it was present in early January, mid-February to late June (peaking in May and June), October-November, and late December into January of the next year. It was sparse in the central Gulf of Maine with most notable presence in April, connecting to a pulse on the western Scotian Shelf. Over the western Scotian Shelf it was present through much of the year, except May, June, and August. Peak abundances for this section occurred in April, October and November.

Seasonality for Massachusetts Bay was fairly steady through the series, with the exception of the 1980' to mid-1990s when latening occurred. Timing for the central Gulf of Maine steadily latened from 1966-1974, becoming much earlier by 1980, and then tending towards later peaks by the end of the series. Western Scotian Shelf timing latened from 1961-1980, then became earlier to 2001, after which it returned to 1960 values.

All three section exhibited positive anomalies in the early 1960s, followed by mostly negative anomalies through 1985. Significant above average conditions occurred in Massachusetts Bay from 1985-1991 and from 1994-2000. Three periods of positive anomalies occurred in the central Gulf of Maine from 1990-2003, and over the western Scotian Shelf positive departures occurred in the early 1990s and especially from 1994-1999.

Chaetognatha, Richardson et al, 2006, hpr traverse - less than 8 mm length.

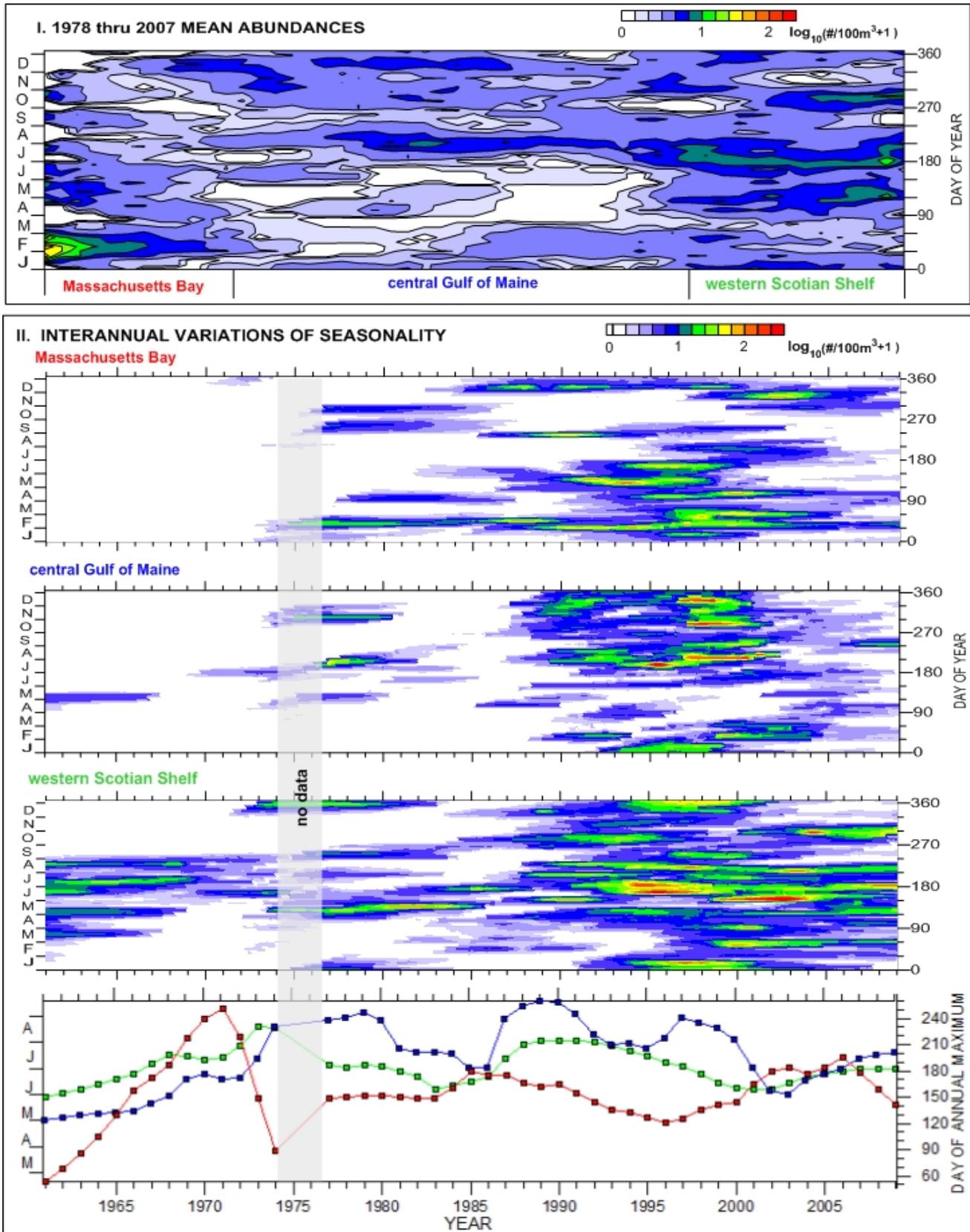


Figure 23. Chaetognatha hpr traverse (less than 8 mm length) variations along the Gulf of Maine Continuous Plankton Recorder transect.

Chaetognatha, Richardson et al, 2006, hpr traverse- less than 8 mm length

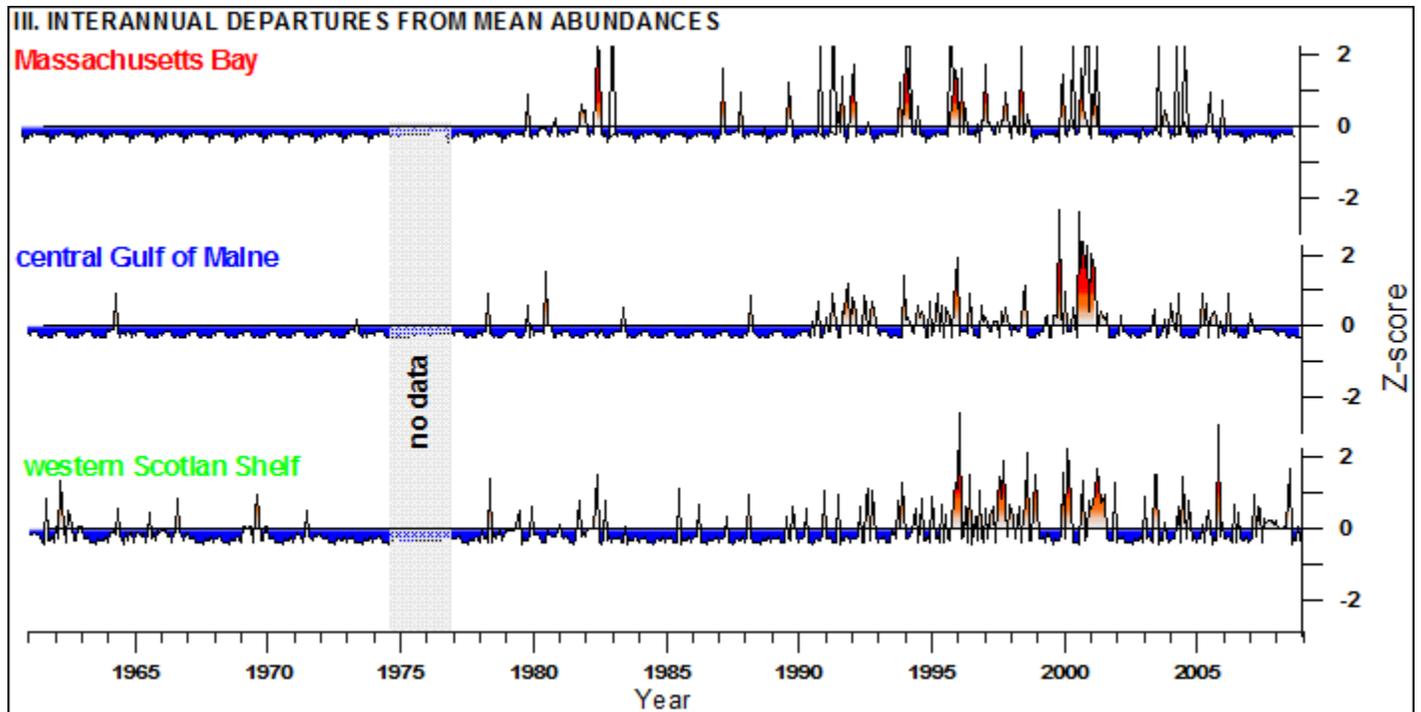


Figure 23 (cont.). Chaetognatha hpr traverse (less than 8 mm length) variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Chaetognaths are transparent, torpedo-shaped plankters commonly called “arrow worms”. Those reported on here, are specimens less than 8 mm in length. They are voracious predators equipped with a series of movable spines on their heads which they use to grab and ingest prey. Chaetognaths are probably one of the main sources of predation pressure on the copepod community and also feed on larval fish, crustaceans, and other chaetognaths. These active predators are also an important food source for fish and other animals higher in the food web.

They were most abundant over the shelf sections of the transect, but except for spring and early summer were present in moderate amounts in the central Gulf of Maine. Peak abundances in Massachusetts Bay occurred in late January, and over the western Scotian Shelf in early May, July, and October.

Examination of the variations of seasonality show that the 1978-2007 mean portrayal is often not representative of the taxon’s space-time distribution. Also, the multiple, seasonal peaks make determination of seasonality changes difficult. There does seem to be a latening of the “day of annual maximum” from the start to the end of the series.

The major pattern in the monthly anomalies was the change from predominantly below average to above average conditions in about 1990. This change persisted on the western Scotian Shelf through the remainder of the series. It persisted to a lesser extent in Massachusetts Bay, but returned to nearer normal in the central Gulf of Maine after 2003.

Euphausiacea, Dana, 1852, furcilia & calyptopis.

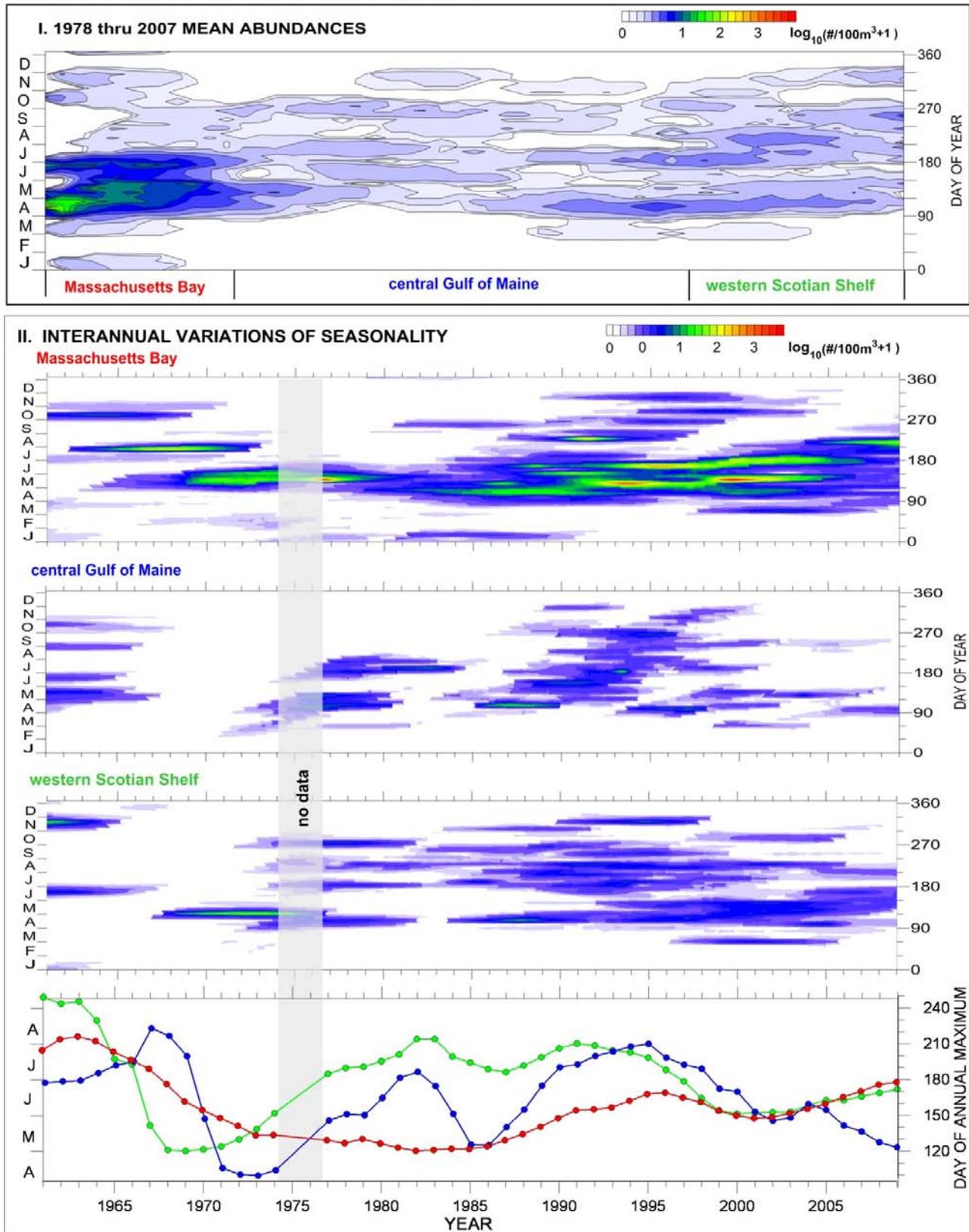


Figure 24. Euphausiacea furcilia and calyptopis variations along the Gulf of Maine Continuous Plankton Recorder transect.

Euphausiacea, Dana, 1852, furcilia & calyptopis

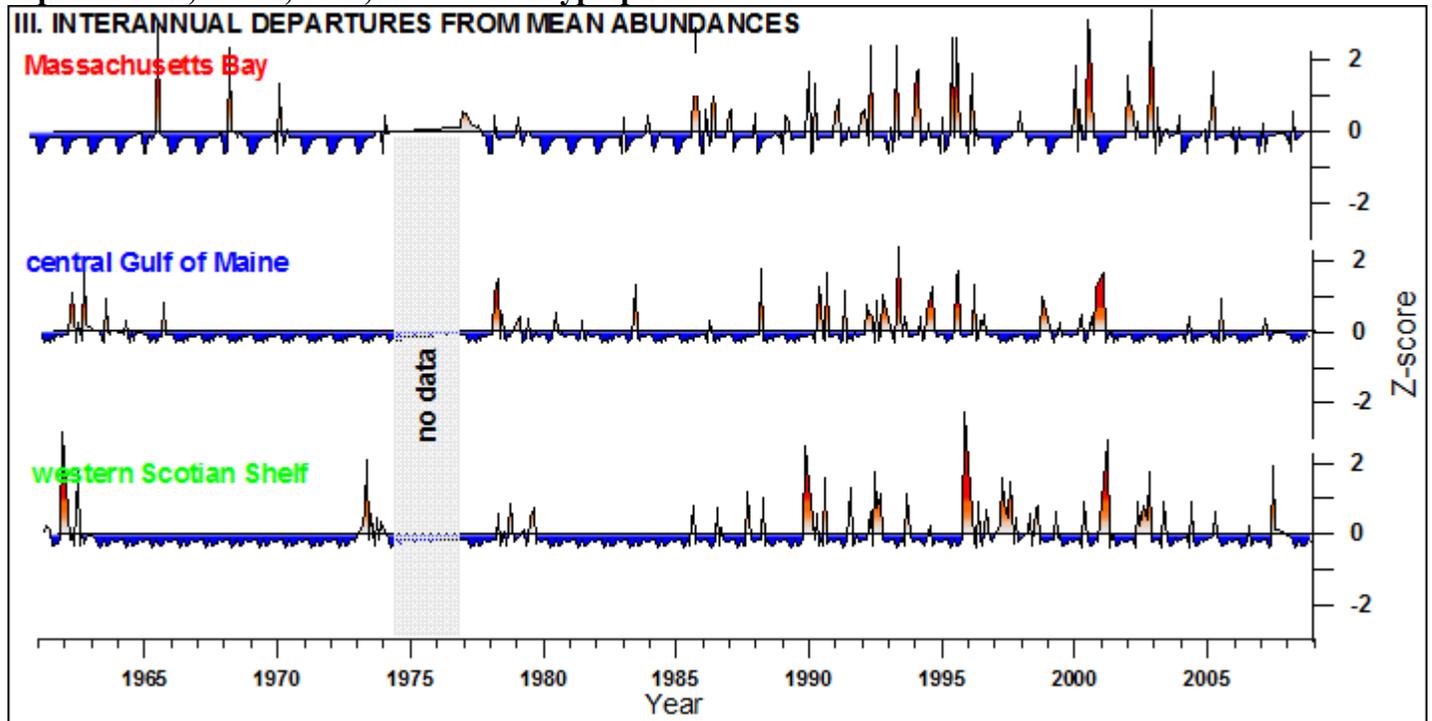


Figure 24 (cont.). Euphausiacea furcilia and calyptopis variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Euphausiids, or krill, are a group of crustaceans found throughout the world's ocean. They are notable for their strong swimming capabilities, and in certain species, they can occur in dense concentrations or swarms. In the Gulf of Maine, they are an important trophic connection in the pelagic food web. They feed near the bottom of the food chain on plankton and are important prey items for many commercial fish species and marine mammals. Three life stages are separated during CPR examination. The combined furcilia and calyptopis stages are reported here.

Mean abundances were concentrated in spring and early summer over Massachusetts Bay; and during April-May, and July-September in the eastern part of the central Gulf of Maine, and on the western Scotian Shelf. Highest abundances are found over Massachusetts Bay.

The day of annual maximum for all sections in the early 1960s was considerably later than subsequent years, especially than after 2000. Massachusetts Bay seasonality from 1965-2005 was fairly steady, after which changes occurred. Higher abundances generally coincided with prolonged seasonal highs.

Negative conditions in Massachusetts Bay dominated the 1961-1990 period, except for positive spikes in 1965, 1968, 1970, and 1985. 1990-1996 was above average, followed by a four year low. Positive departures returned from 2000-2004, followed by slightly lower values to the end of the series. The pre-1990 low period in the central Gulf of Maine was broken in the early 1960s, and in 1978 by brief positive departures. Subsequent anomalies resembled those in Massachusetts Bay with a longer low period starting in 2001. The western Scotian Shelf followed the central Gulf of Maine to a large extent, except for a positive departure in 1973 and more mixed conditions after 2003.

Euphausiacea, Dana, 1852, post calyptopis.

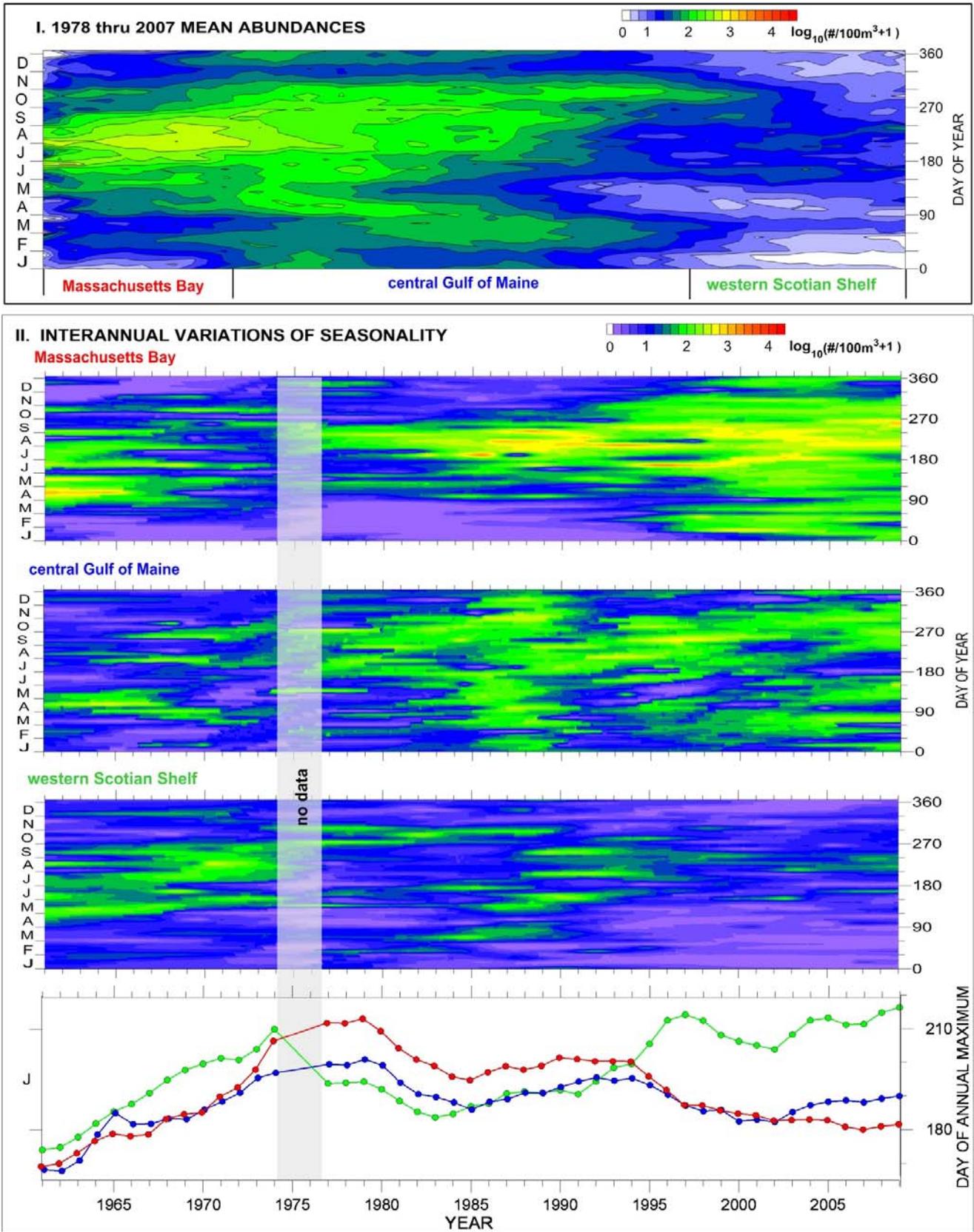


Figure 25. Euphausiacea post calyptopis variations along the Gulf of Maine Continuous Plankton Recorder transect.

Euphausiacea, Dana, 1852, post calyptopis

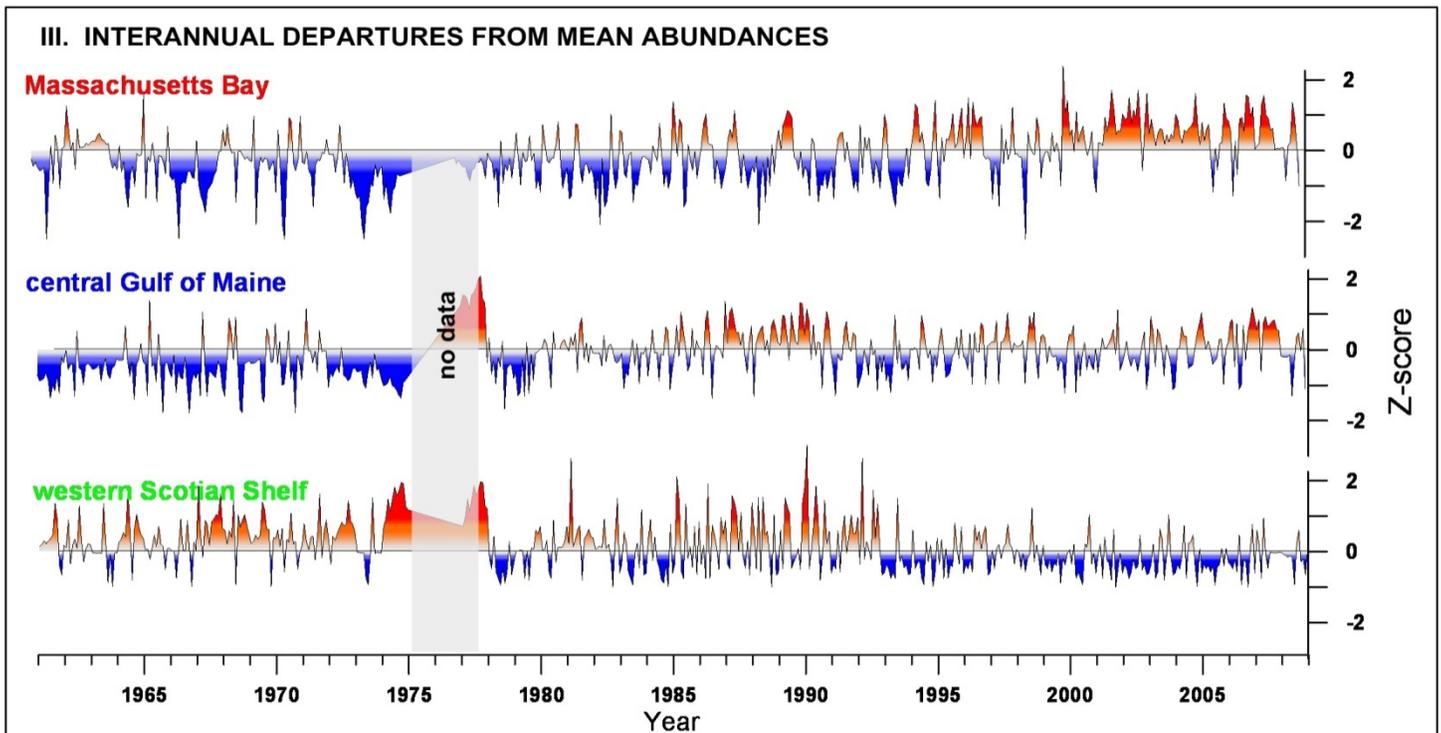


Figure 25 (cont.). Euphausiacea post calyptopis variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Euphausiids, or krill, are a group of crustaceans found throughout the world's ocean. They are notable for their strong swimming capabilities, and in certain species, they can occur in dense concentrations or swarms. In the Gulf of Maine, they are an important trophic connection in the pelagic food web. They feed near the bottom of the food chain on plankton and are important prey items for many commercial fish species and marine mammals. Three life stages are separated during CPR examination. The post calyptopis stage is reported here.

Mean abundances in Massachusetts Bay are low to moderate from January-April. Values increased, peaking in August, and slowly decreased, reaching seasonal lows by November. A more prolonged high period was seen in the western portion of the central Gulf of Maine, with higher values extending through much of the year, but without a clear seasonal peak. The western Scotian Shelf had considerably lower values (zero abundance in January) than the rest of the transect. Highest period was from April to October.

A general latening trend was seen in the day of annual maximum values for all three sections of the transect. This was most marked for the western Scotian Shelf.

Anomalies in Massachusetts Bay were predominantly negative till 1994 after which the reverse was the case. In the central Gulf of Maine below average conditions prevail till 1980, positive departures from 1984-1991, mixed values till 2007 followed by over a year of above average departures. The western Scotian Shelf pattern as a near mirror image of that for Massachusetts Bay with positive departures dominating from 1961-1993 and negative anomalies prevailing thereafter.

Euphausiacea, Dana, 1852, nauplius.

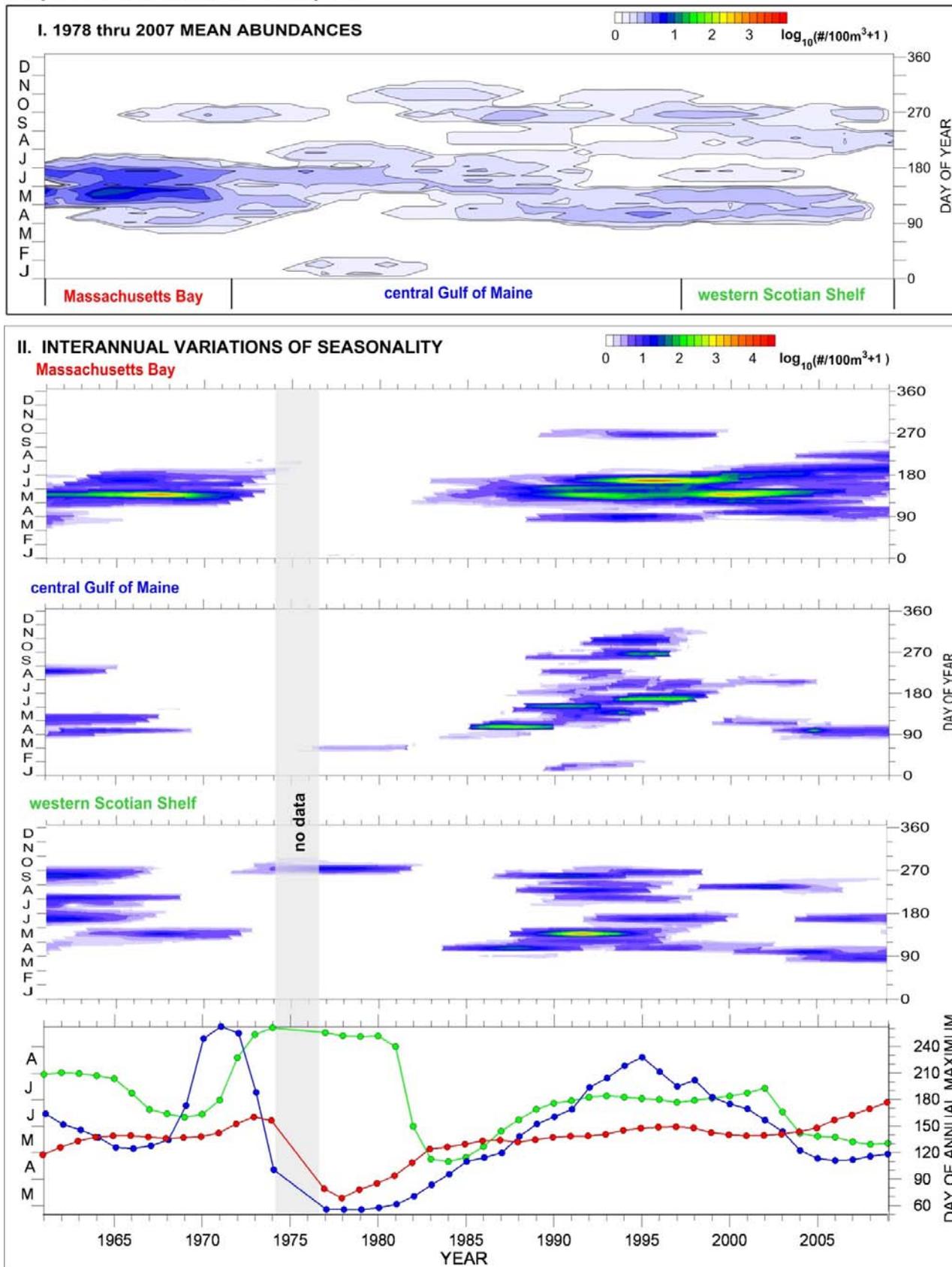


Figure 26. Euphausiacea nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

Euphausiacea, Dana, 1852, nauplius

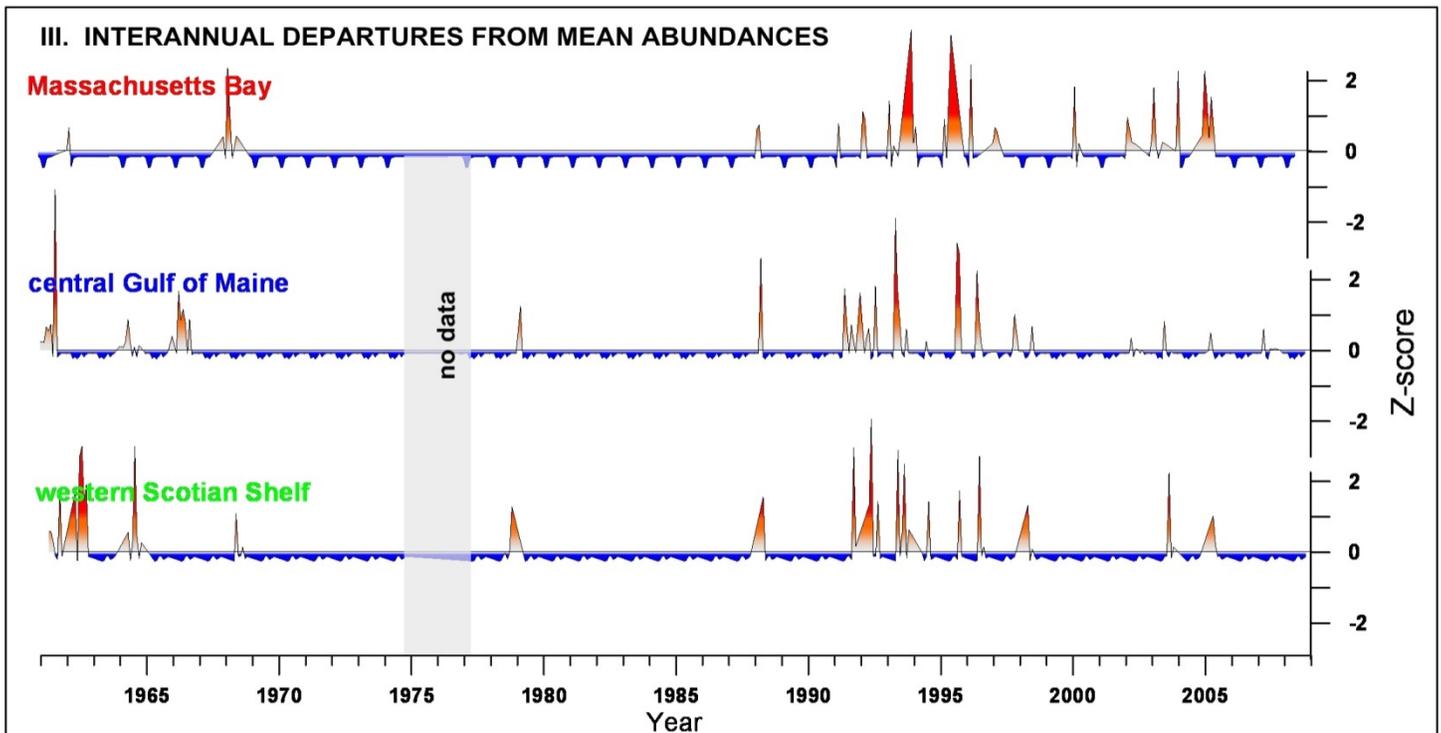


Figure 26 (cont.). Euphausiacea nauplius variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Euphausiids, or krill, are a group of crustaceans found throughout the world's ocean. They are notable for their strong swimming capabilities, and in certain species, they can occur in dense concentrations or swarms. In the Gulf of Maine, they are an important trophic connection in the pelagic food web. They feed near the bottom of the food chain on plankton and are important prey items for many commercial fish species and marine mammals. Three life stages are separated during CPR examination. The nauplius stage is reported here.

Nauplii were nearly absent from the Gulf of Maine except for the April to mid-July period. Values peaked in May in Massachusetts Bay, and declined to the eastward. Three low abundance time-space patches occur in late September in all three sections.

Seasonality was fairly steady in Massachusetts Bay, but was interrupted from 1974-1985. The more temporally disconnected pattern in the central Gulf of Maine was also interrupted during this period, as can be seen in the day of annual maximum plot. This period of interruption differs on the western Scotian Shelf, where a late season event was in evidence. The prolonged high period for the eastern two sections seen from the mid-1980s to 1997 reverted to the several short pulses seen earlier in the series.

Negative departures dominated all three sections until the late 1980s. A few notable exceptions were Massachusetts Bay, 1968; central Gulf of Maine, 1961 and 1966; and western Scotian Shelf, 1961, 1962, 1964, and 1978. Above average conditions prevailed during the 1990s in all sections, and during the early 2000s over Massachusetts Bay and the western Scotian Shelf.

Centropages hamatus, Lilljeborg, 1853, copepodite stages 4-6.

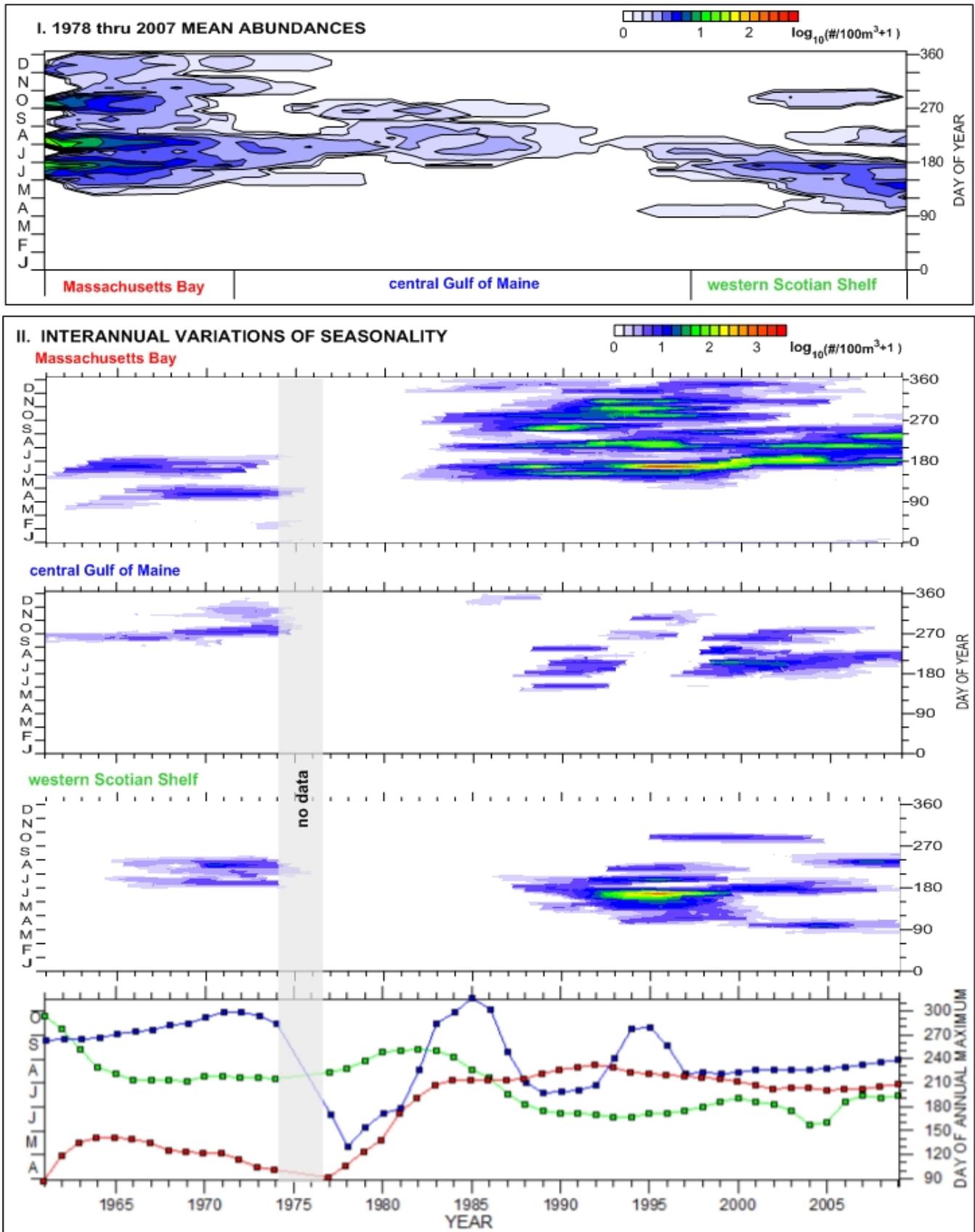


Figure 27. *Centropages hamatus* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Centropages hamatus, Lillgeborg, 1853, copepodite stages 4-6

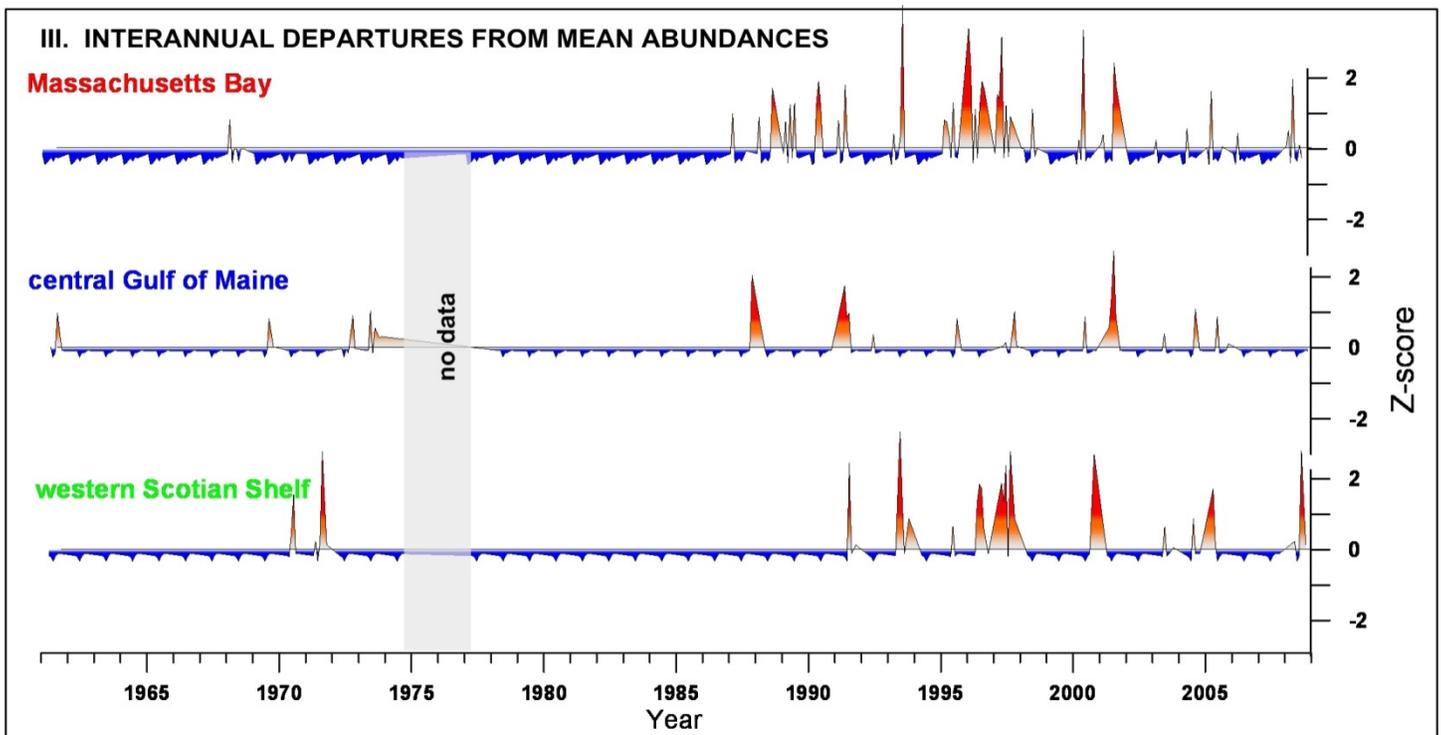


Figure 27 (cont.). *Centropages hamatus* c.4-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

This calanoid copepod is one of the most abundant members of the zooplankton community found within shelf waters of the North Atlantic. *Centropages hamatus* has a wide latitudinal range and a strong onshore-offshore abundance gradient. The copepod is omnivorous and its abundance in the northern part of its range appears to be most influenced by food limitation. The species has been found to produce subitaneous eggs during breeding season and resting ones in response to temperature cues.

Specimens were absent in Massachusetts Bay CPR samples prior to May, had a brief peak in July, a secondary peak in October, and then declined towards the end of the year. A good deal of this time they are absent very near the western end of the transect. The Massachusetts Bay pattern extends into the western portion of the central Gulf of Maine during July through September. The copepod was absent from the western Scotian Shelf until mid-April, reaching maximum abundance in June, followed by a rapid decline. Small time-space patches occurred in August and October on the eastern end of the transect.

The May to December period of production seen in Massachusetts Bay means was not evident prior to 1994. An extended period of production on the western Scotian Shelf coincided with years of higher abundance, e.g., 1990-2005.

With only a few exceptions, the period prior to 1987 had negative departures from the 1978-2007 means. From then until the early 2000s above average conditions occurred much of the time, especially in Massachusetts Bay and on the western Scotian Shelf. Thereafter anomalies in Massachusetts Bay were mixed, in the central Gulf of Maine, mostly negative, and on the western Scotian Shelf, mixed.

Bivalvia, Linnaeus, 1758, larva.

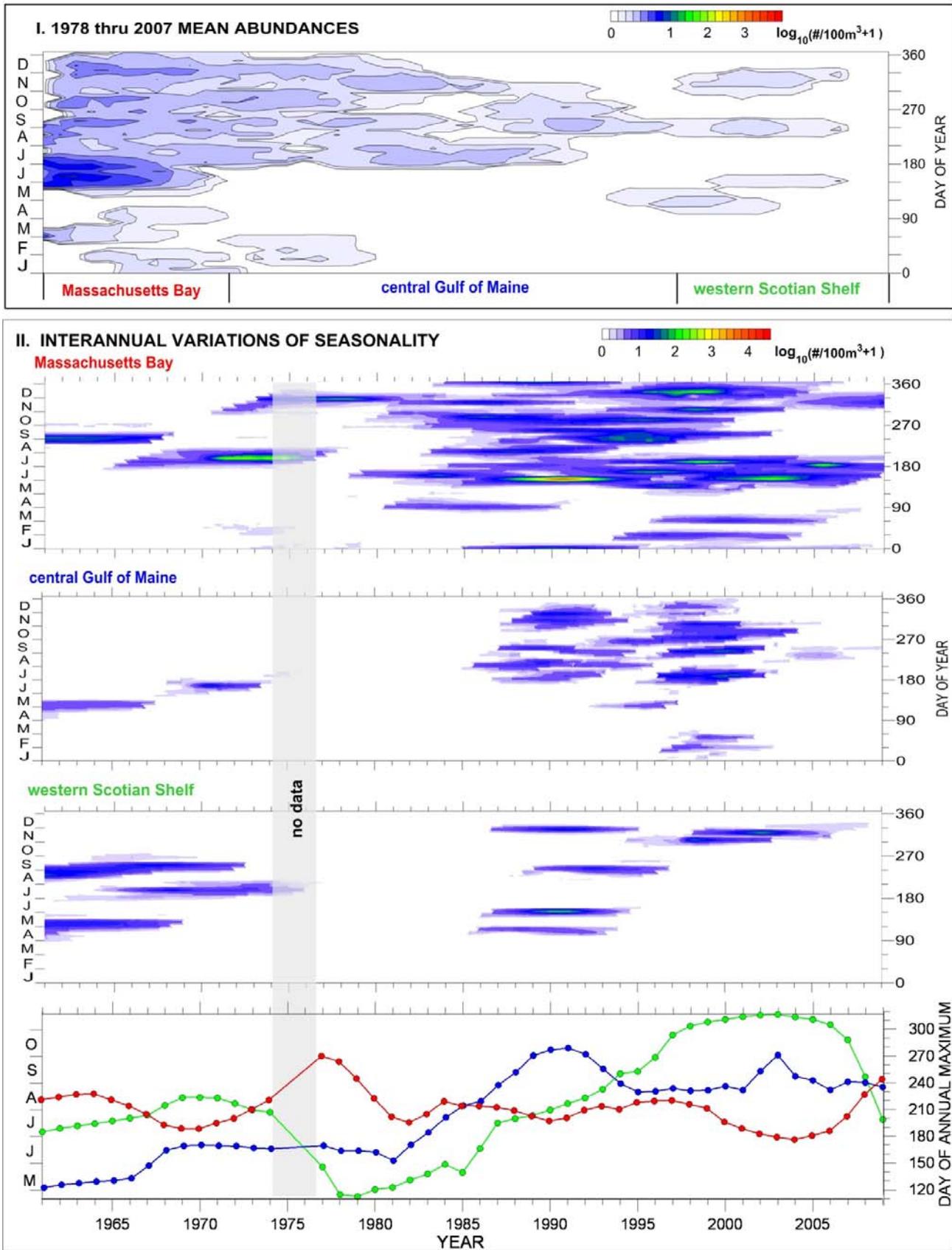


Figure 28. Bivalvia larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

Bivalvia, Linnaeus, 1758, larva

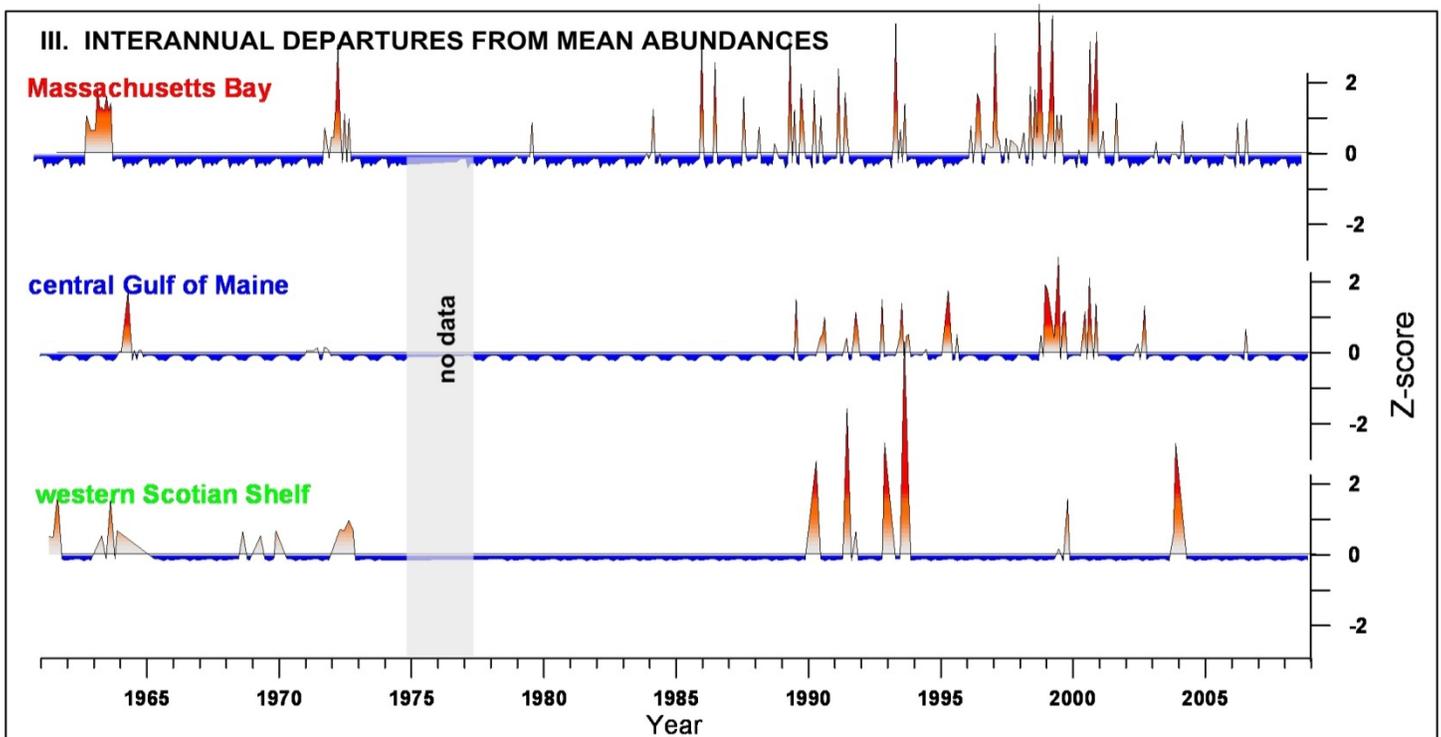


Figure 28 (cont.). *Bivalvia* larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Bivalves are a class of mollusks whose adults are easily recognized by their two-halved shell. The life cycle of most marine bivalves include a free-swimming veliger larval stage that is routinely captured by the CPR. The larva looks like a miniature bivalve with a ciliated structure that extends outside the shell and is used for both swimming and particulate food collection. Most larvae feed on phytoplankton for weeks to months before they settle to the seabed and transform into an adult.

Mean patterns showed bivalve larvae very nearly absent from the CPR samples on the western Scotian Shelf. In Massachusetts Bay they first appeared briefly in early March and then in late May, reaching peak abundance over inner Massachusetts Bay in June. Slightly lower values persisted till the end of the calendar year. After August, larvae were absent from the western extreme of Massachusetts Bay. Tongues of the Massachusetts Bay abundance extended into the western portion of central Gulf of Maine, particularly in July and November.

Years prior to the beginning of the 1978-2007 base period exhibited different season patterns than those during the base period. This can also be seen in the latened day of annual maximum curves for the central Gulf of Maine and the western Scotian Shelf in the later years.

Massachusetts Bay anomalies were largely negative until the late 1980s, with the exception of 1962-1963 and 1972-1973. Positive departures, with occasional reversal, continued until 2002. Below average conditions prevailed after 2002. The central Gulf of Maine departures were equally negative until the early to mid-1990s, followed by Massachusetts Bay-like positive anomalies lasting until about 2002, and followed by below average conditions to the end of the series. On the western Scotian Shelf small departures from the near-zero mean abundances produced dramatic Zscores. Nonetheless, the pattern there was somewhat similar to the other two sections.

Chaetognatha, Richardson et al, 2006, hpr eyecount- greater than or equal to 8 mm length.

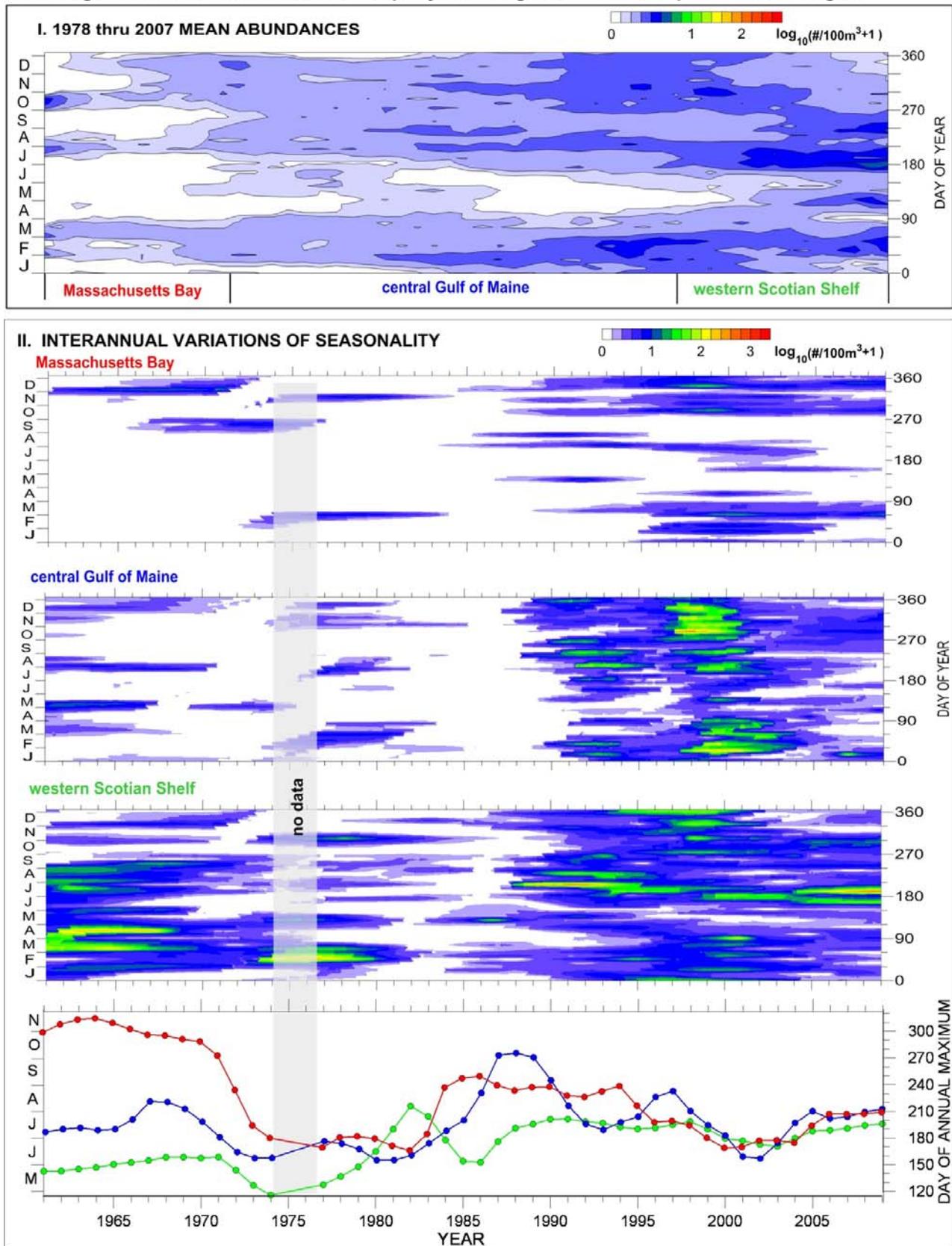


Figure 29. Chaetognatha hpr eyecount (≥ 8 mm length) variations along the Gulf of Maine Continuous Plankton Recorder transect.

Chaetognatha, Richardson et al, 2006, hpr eyecount- greater than or equal to 8 mm length

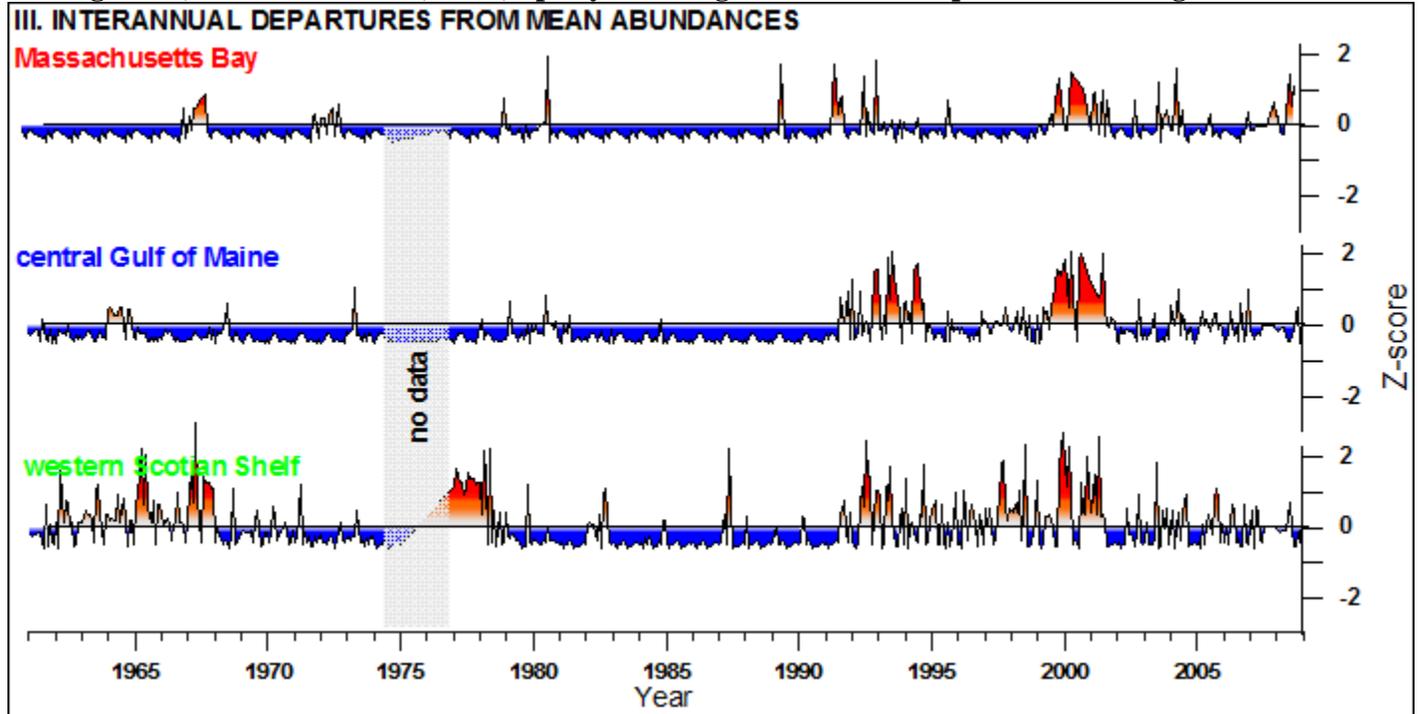


Figure 29 (cont.). Chaetognatha hpr eyecount (≥ 8 mm length) variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Chaetognaths are transparent, torpedo-shaped plankters commonly called “arrow worms”. Those reported on here, are specimens greater than or equal to 8 mm in length. They are voracious predators equipped with a series of movable spines on their heads which they use to grab and ingest prey. Chaetognaths are probably one of the main sources of predation pressure on the copepod community and also feed on larval fish, crustaceans, and other chaetognaths. These active predators are also an important food source for fish and other animals higher in the food web.

Mean patterns showed a good portion of Massachusetts Bay through the year, most of the central Gulf of Maine from April-June, and portions of the western Scotian Shelf during January, April, and December bereft of these chaetognaths. Major concentrations occurred from January to March; from June-July; and September-December over the eastern two transect sections.

Day of annual maximum values for the three sections, disparate during the 1961-1970 period, converged especially after 1990, indicating peak abundances in July. Pulses through most of the calendar year over the eastern two sections persisted even in the low abundance years.

Pre-1990 anomalies in Massachusetts Bay were largely negative. The early 1990' were above average, the late 1990s negative, 1999-2002 above average, and the rest of the series somewhat mixed. The central Gulf of Maine displayed departures very much like those of Massachusetts Bay. Over the western Scotian shelf positive departures dominated from 1962-1968, followed by a below average period (briefly interrupted in 1977) until 1991. The rest of the series for the western Scotian Shelf follows patterns in the other two sections.

Hyperiidæ, (Boeck, 1872), unstaged.

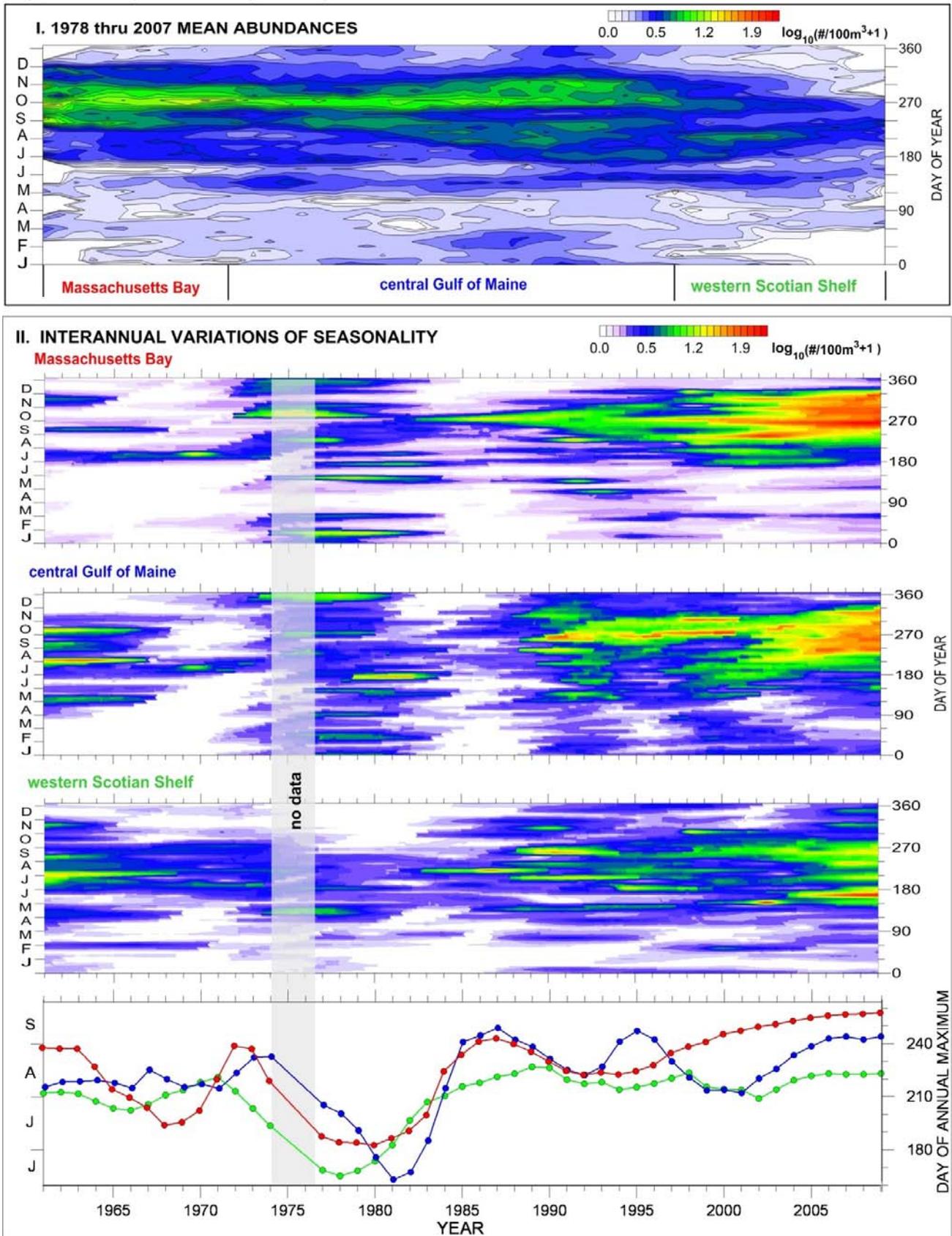


Figure 30. Hyperiidæ unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

Hyperiid, (Boeck, 1872), unstaged

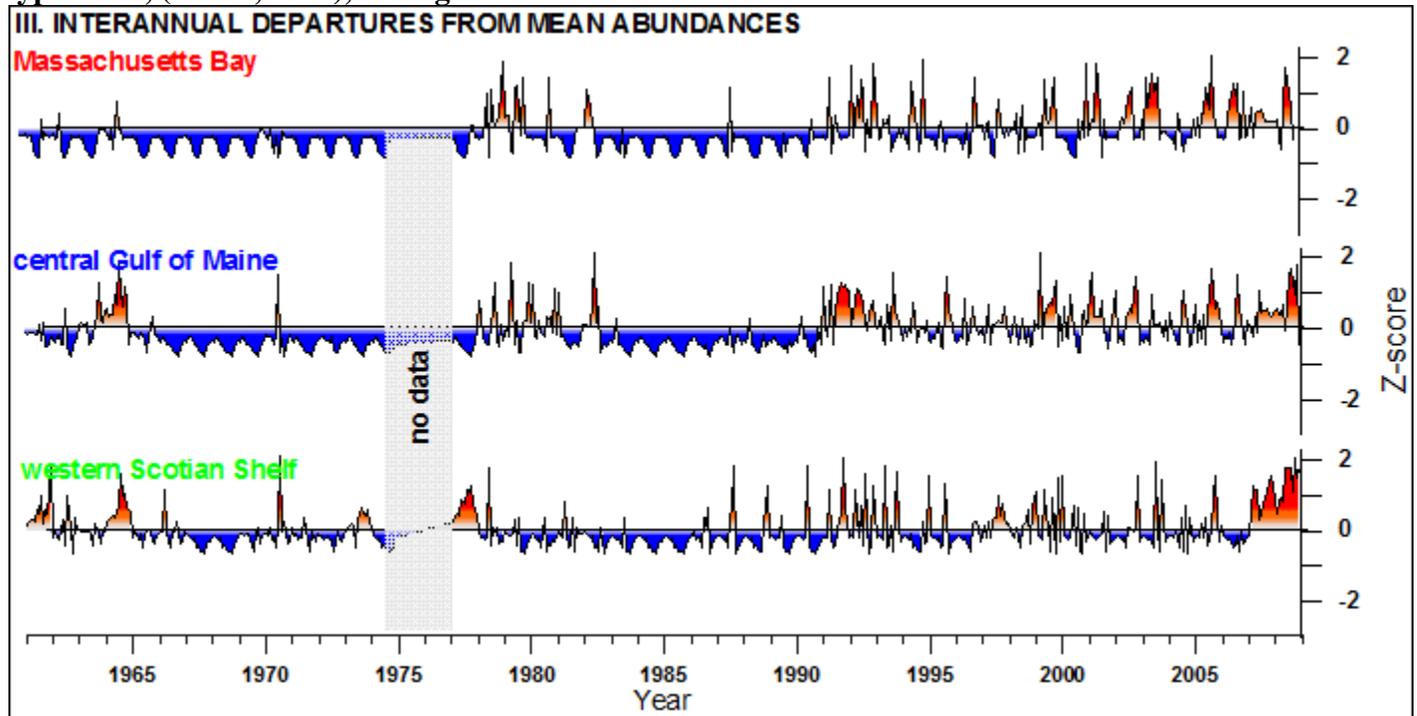


Figure 30 (cont.). Hyperiid unstaged variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Hyperiid amphipods are marine pelagic crustaceans that occur in all oceans. Hyperiiids have a laterally compressed body with large compound eyes that cover all of the head. Many species are mutualistic or parasitic with gelatinous organisms during some part of their life cycle. Pelagic amphipods are known to occur in dense swarms and are the preferred prey of many seabirds, fish, and whales.

They were absent to present in low abundance across much of the transect during the first third of the year. A rapid increase began in mid-April, peaking by early August (somewhat earlier on the western Scotian Shelf). Decline began in November (more rapidly at the transect extremes), and reached annual lows by December.

Seasonal timing in Massachusetts Bay from 1961-1967 became earlier, then latened till 1972. Timing in the other two sections remained steady during this period. The day of annual maximum then occurred progressively earlier till the late 1970s/early 1980s, followed by a latening till the late 1980s. This timing latened slightly in Massachusetts Bay, but remained fairly steady in the other two sections through the rest of the series. There appeared to be a slight latening trend in the day of annual maximum through the series.

Sustained positive anomalies in Massachusetts Bay occurred in 1978-1979, 1992, 1994, and after 2004. Except as just mentioned, the period from 1961-1991 was below average. The same below average period in the central Gulf of Maine was interrupted by positive departures in 1963-1964 and 1978-1982. After 1991, above average values dominated. From 1961-1964 positive anomalies existed on the western Scotian Shelf; largely negative conditions prevailed until 1991 with the exception of high values in 1977; above average condition occurred in 1991-1993, 1997-2000, and especially beginning in 2007. Other periods were mixed.

Paraeuchaeta norvegica, (Boeck 1872), copepodite stages 3-6.

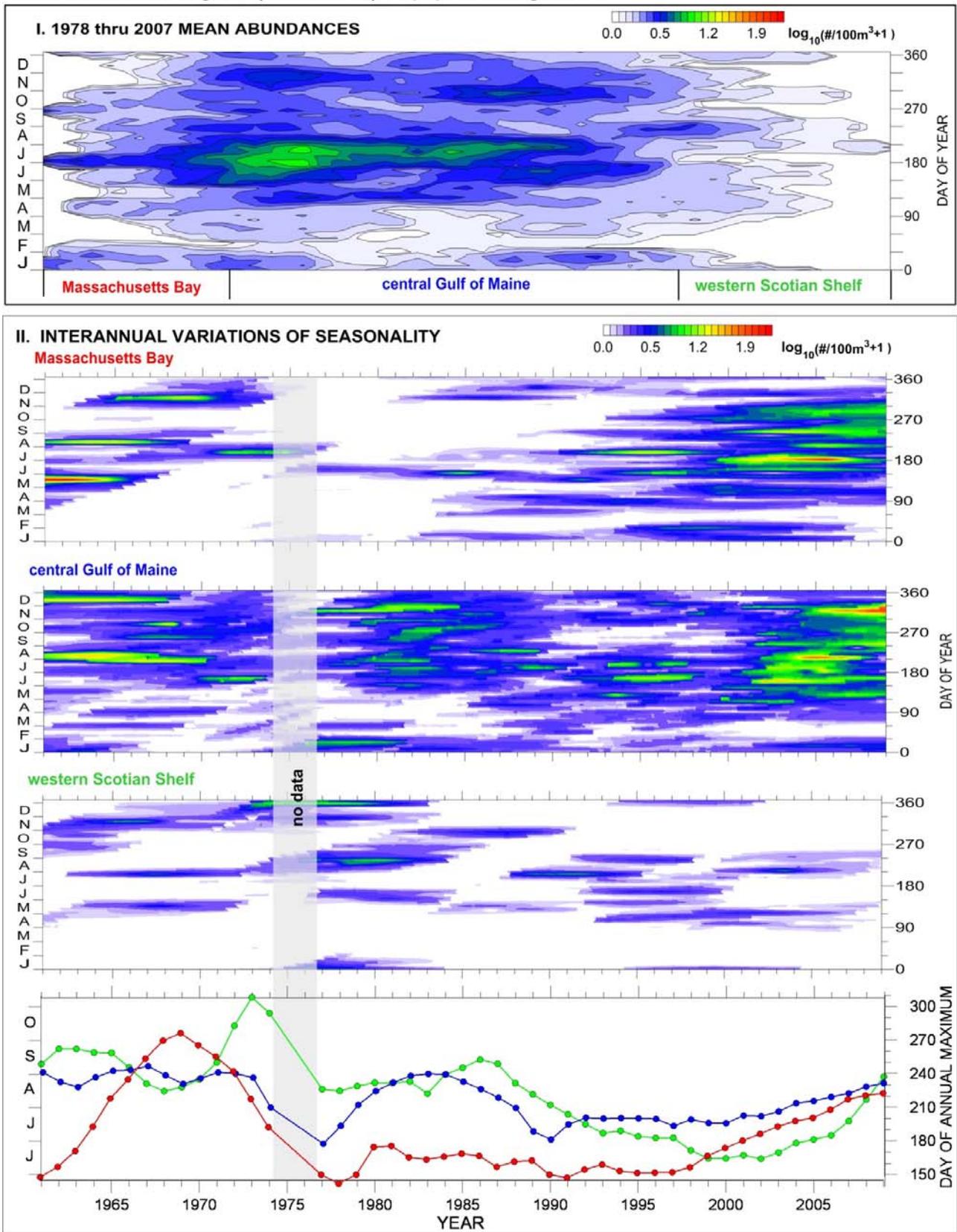


Figure 31. *Paraeuchaeta norvegica* c. 3-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Paraeuchaeta norvegica, (Boeck 1872), copepodite stages 3-6

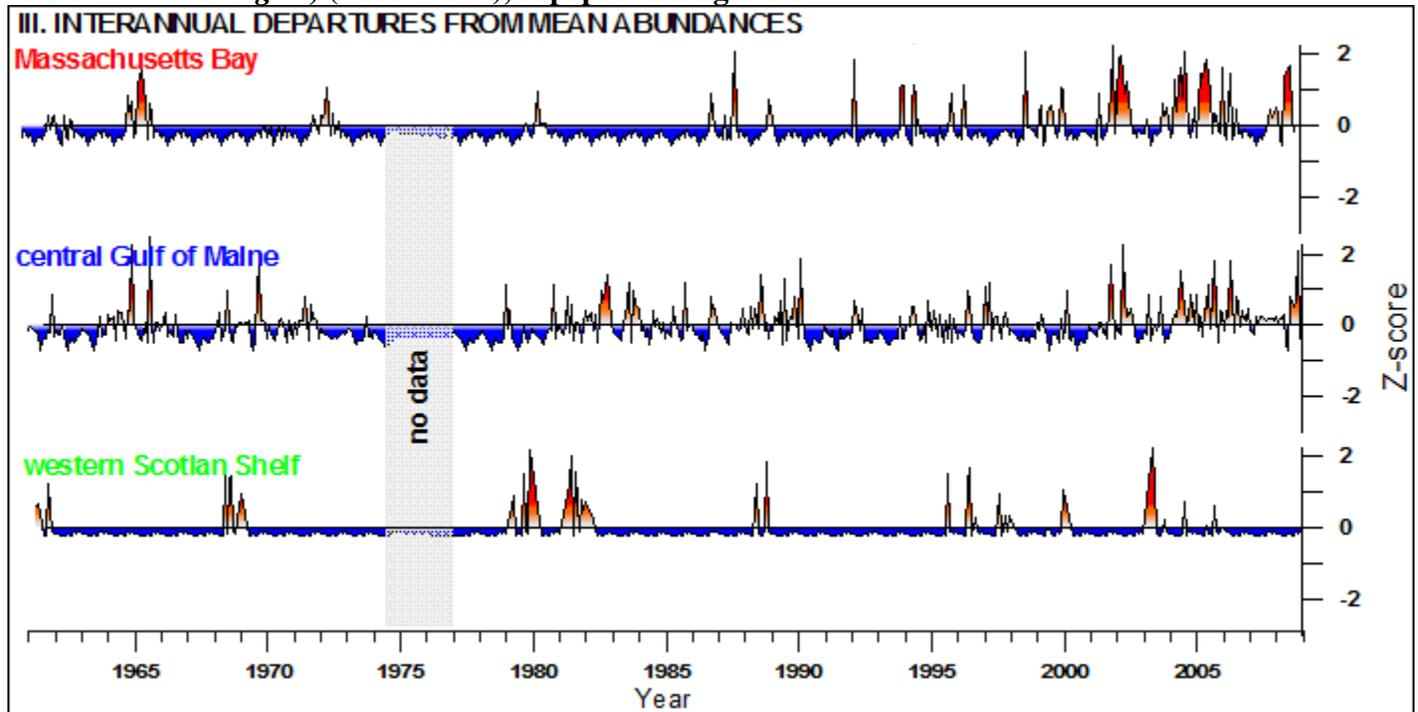


Figure 31 (cont.). *Paraeuchaeta norvegica* c. 3-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Paraeuchaeta norvegica is a large carnivorous, calanoid copepod that has a widespread distribution in the North Atlantic. It is a strong vertical migrator that avoids visual predators by living deep during the day and ascending into the upper waters to feed at night. It is a tactile predator that is very efficient at capturing small copepods. In spite of its known vertical migration, its abundance ranking and consistency of identification and staging through the series, resulted in atlas inclusion.

Except for brief periods in January, early July, and late September, this copepod was absent in samples from the western extremes of the transect, absent throughout the year during February, and absent from the easternmost 50 km of the transect. It existed from March to year's end, peaking over the western portion of central Gulf of Maine in late June and July.

Seasonal patterns varied considerably during the series for all sections of the transect. However, after 1990 they became more steady, with more similar peak times, and a slight latening to the end of the series.

Brief periods of above average conditions occurred in Massachusetts Bay from 1961 through about 2000. Otherwise this period was dominated by negative anomalies. From 2002 to 2007, and in 2008, departures were above average. Except for 1972-1980 when negative departures dominated in the central Gulf of Maine, conditions were mixed until 2001. Above average abundance prevailed to the end of the series. Absent to very low abundances on the western Scotian Shelf especially reduce the value of the negative Zscores. However, numerous periods of above average abundances are indicated.

Harpacticoida, G. O. Sars, 1903, copepodite stages 1-6.

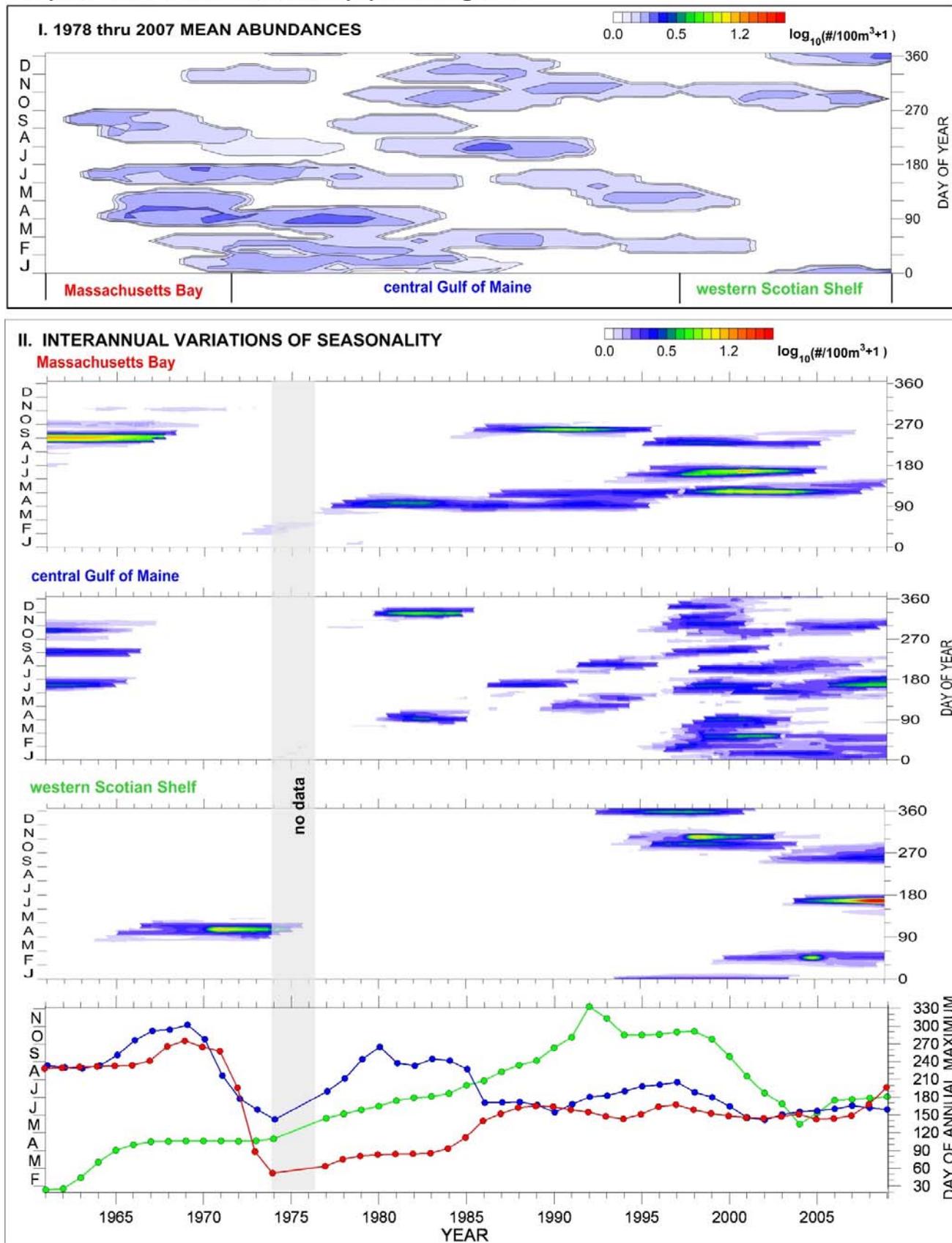


Figure 32. Harpacticoida c.1-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Harpacticoida, G. O. Sars, 1903, copepodite stages 1-6

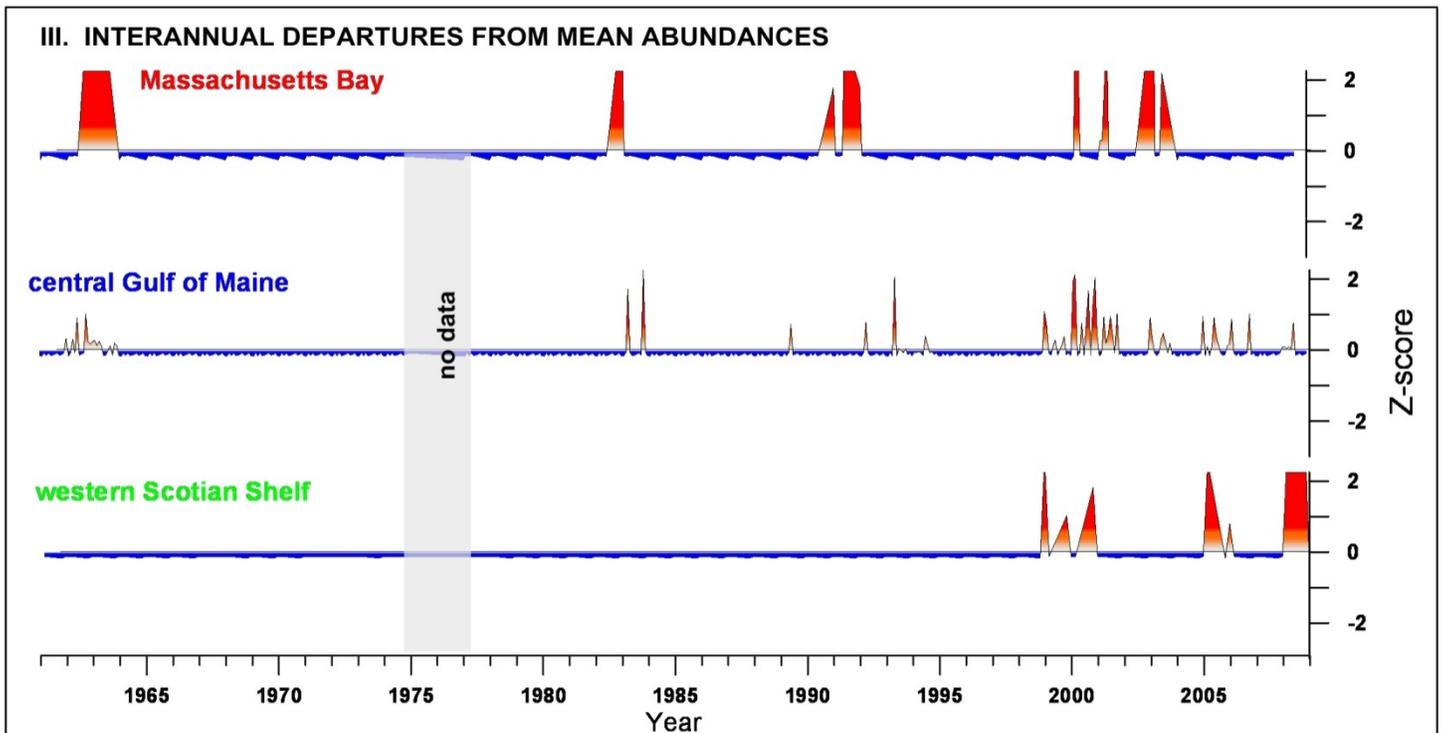


Figure 32 (cont.). Harpacticoida c.1-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Harpacticoids are an order of copepods distinguished by the presence of only a very short pair of first antennae. They typically have a wide abdomen and often there are not obvious divisions between the main regions of the body. The vast majority of them are benthic, but representatives of the genus *Alteutha* are frequently captured by plankton samplers in the shelf waters of the northwest Atlantic.

The 1978-2007 means provided little to aid in describing this taxon's seasonal cycle or spatial preference. Small areas of abundances surrounded by absences were spread throughout most of the time-space domain. The largest contiguous area appeared during March and April over the outer Massachusetts Bay and western portion of the central Gulf of Maine.

The lack of a clearly defined seasonal cycle precluded any simple discussion of interannual changes in seasonality.

As with other relatively low abundance taxa, the Zscore time series of Harpacticoids illustrated times of positive departures, but offers less detail when departures were negative (usually zero abundance). Aside from the notable positive anomalies in Massachusetts Bay and the central Gulf of Maine in the early 1960s and early 1980s, the early years of the series had below average abundances. Isolated positive anomalies in Massachusetts Bay occurred in the early 1990s and 2000s. A more sustained period of above average abundance occurred in the central Gulf of Maine after 1999. From 1999-2001, and during 2005 and 2008 positive anomalies occurred on the western Scotian Shelf.

Polychaeta, larva.

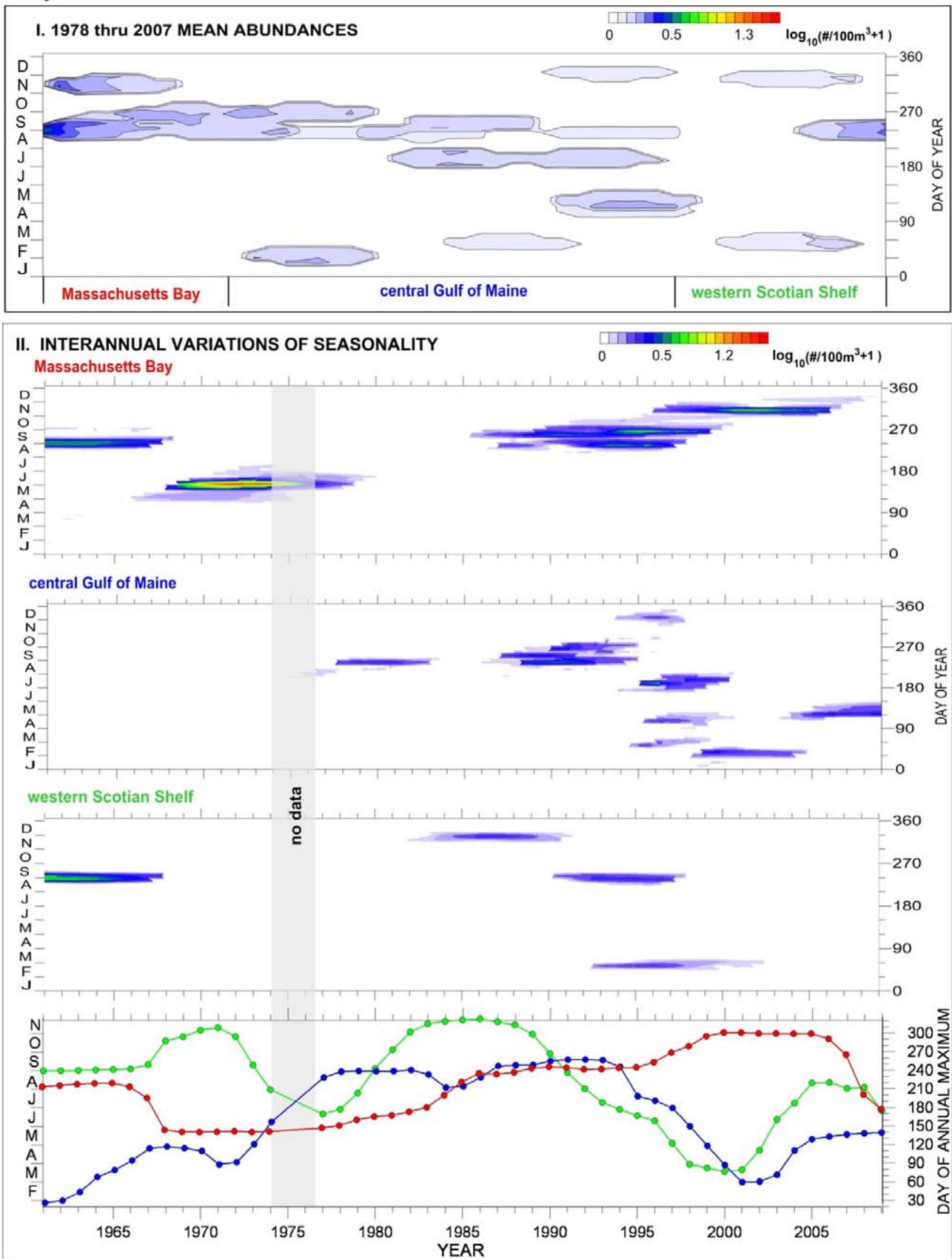


Figure 33. Polychaeta larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

Polychaeta, larva

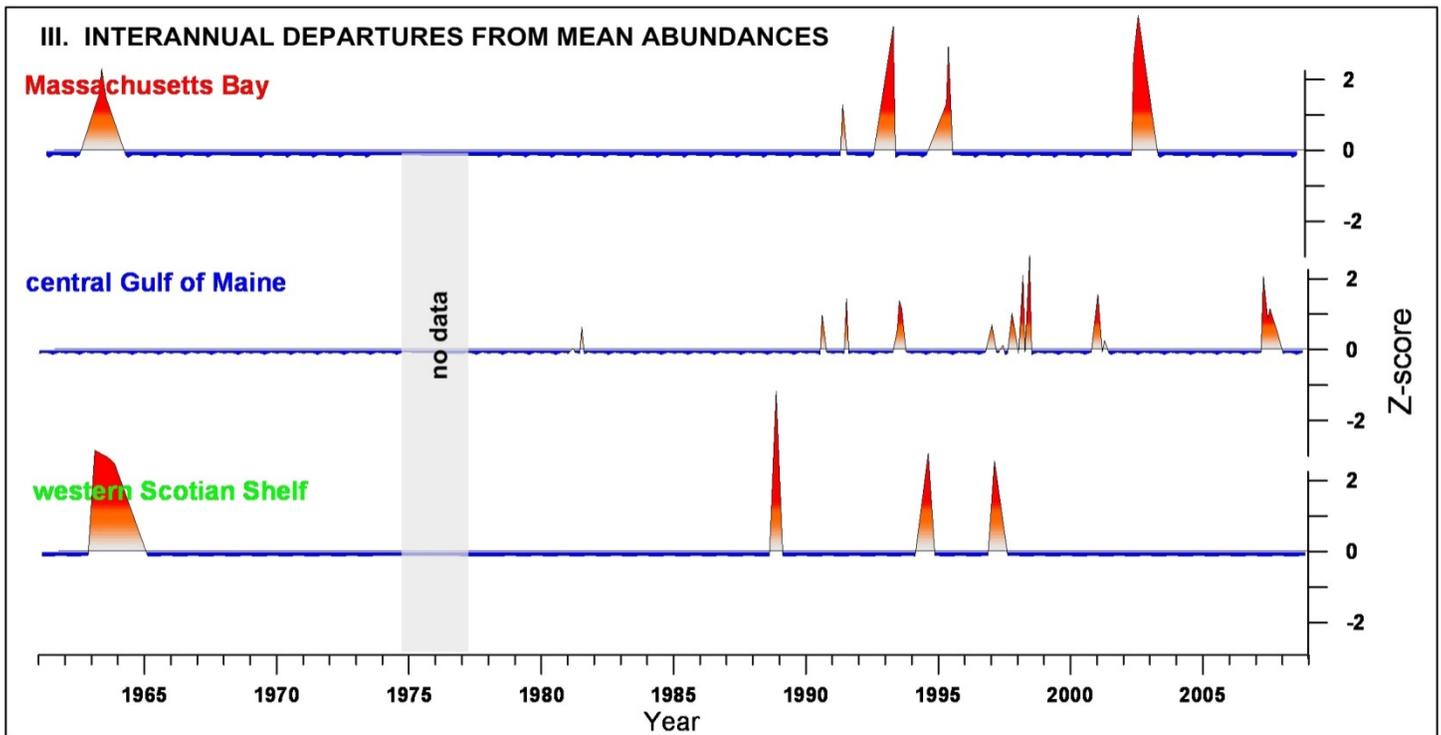


Figure 33 (cont.). Polychaeta larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The polychaetes are a large class of segmented worms that can be found on the bottom of the deepest oceans, floating free near the surface, or burrowing in the mud and sand of the beach. The life history of many polychaetes is unknown, but studies have shown that there is an enormous diversity of reproductive strategies. Some species have eggs that hatch into a planktonic trochophore larva that can last a few hours or several weeks. The transparent larva usually weakly swims with ciliated girdles and, during certain periods, can be a major component of the zooplankton community.

Isolated catches of these larvae occurred in all three sections of the transect, and at most times except early winter and early spring. Major abundances were concentrated near inner Massachusetts Bay in late April/early May, and again in November. On the eastern extreme of the transect polychaete larvae showed their highest abundance in late August/early September.

The day of annual maximum values for Massachusetts Bay showed a consistent latening from 1968 to 2000. In the central Gulf of Maine these values were relatively later in the year from 1977-1992. From 1986 to 2000 this peak occurred progressively earlier over the western Scotian Shelf. Like several other taxa, the peaks for the three transect sections converged near the series end.

Abundances in the three sections prior to 1989 were below the 1978-2007 means, except over the shelf sections in 1962-1965. Positive anomalies occurred in Massachusetts Bay in the 1990s and in 2003. Above average conditions in the central Gulf of Maine occurred through the 1990s and in 2007, and on the western Scotian Shelf in 1988, 1994, and 1997.

Osteichthys, egg.

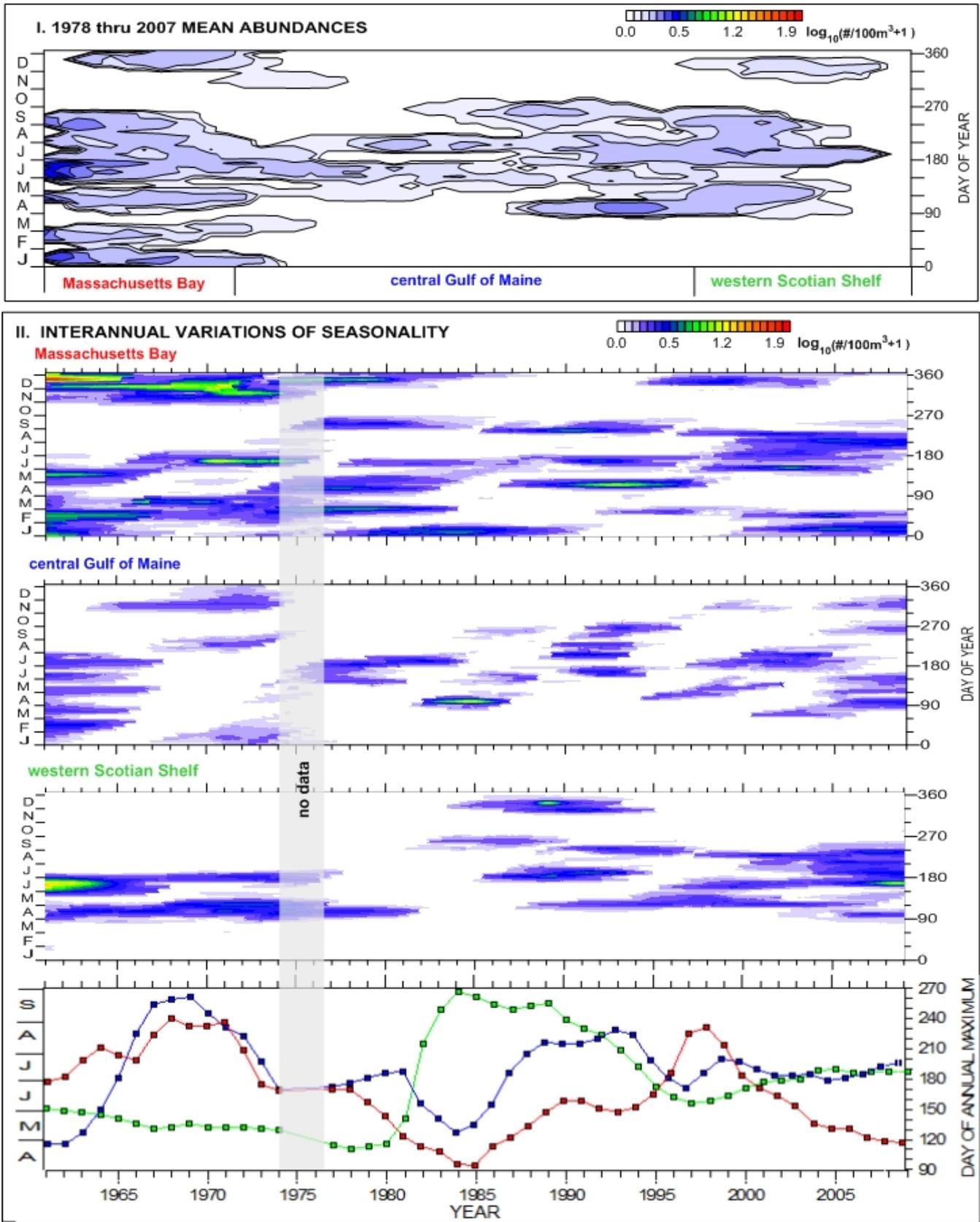


Figure 34. Osteichthys egg variations along the Gulf of Maine Continuous Plankton Recorder transect.

Osteichthys, egg

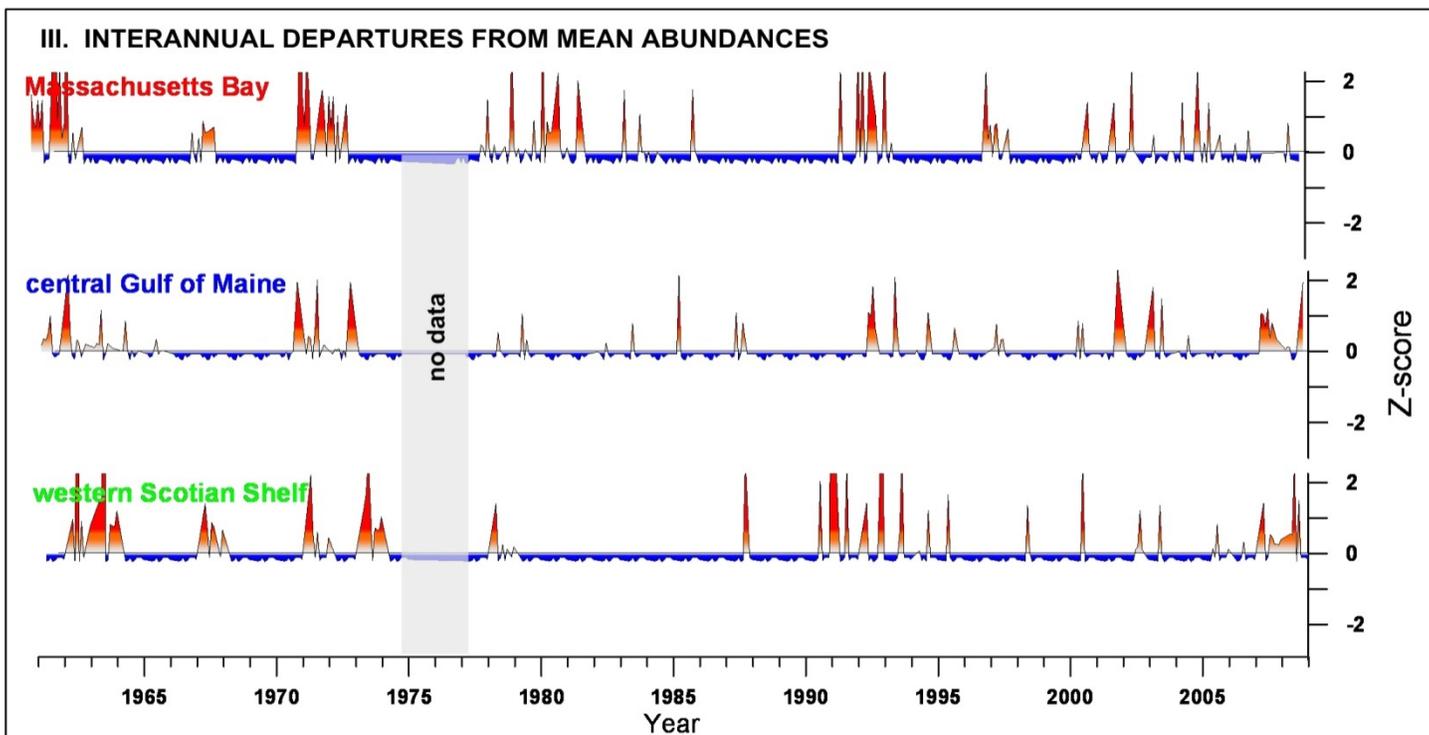


Figure 34 (cont.). Osteichthys egg variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The majority of fishes that reproduce in the Gulf of Maine shed their eggs and sperm directly into the surrounding water. The resultant fertilized eggs may float freely in the plankton until they hatch into larvae.

Mean abundances showed multi-pulses of fish eggs in Massachusetts Bay, reflecting the multi-species of fish represented. Fairly distinct pulses occurred in January, February, late April, late May to early July, early August, September, and December. Patches occurred in the central Gulf of Maine in late July and September. Over the outer western Scotian Shelf and into the central Gulf of Maine two high periods occurred: April and May, and late June to mid-September.

Because of the multi-species nature of these samples, comments on change in seasonality are not offered.

Numerous groups of years with above average abundance are seen. Examination of these monthly values, together with knowledge of the different Gulf of Maine fish species spawning times, could reveal useful information.

Decapoda (not Brachyura), Latreille, 1802, larva.

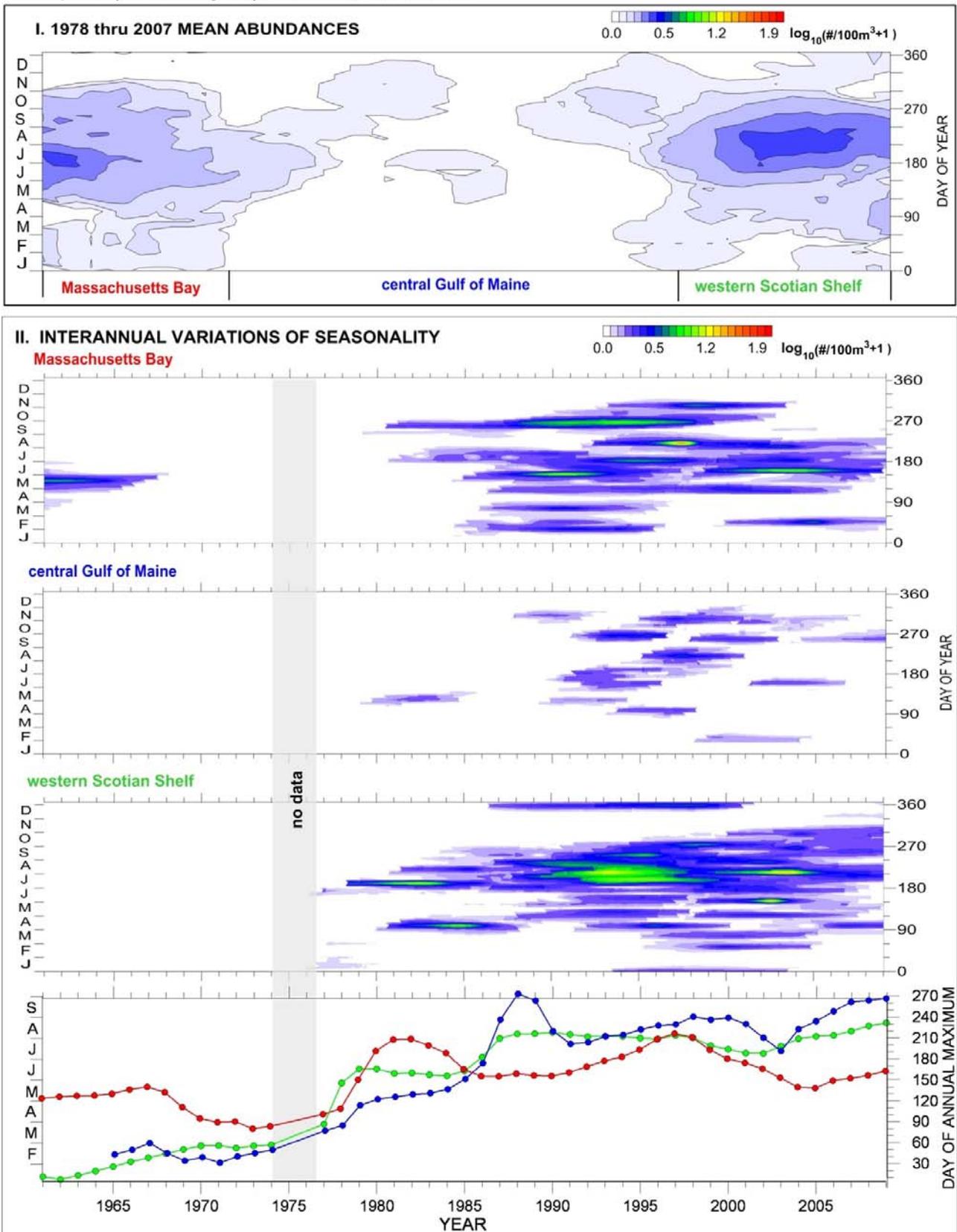


Figure 35. Decapoda (not Brachyura) larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

Decapoda (not Brachyura), Latreille, 1802, larva

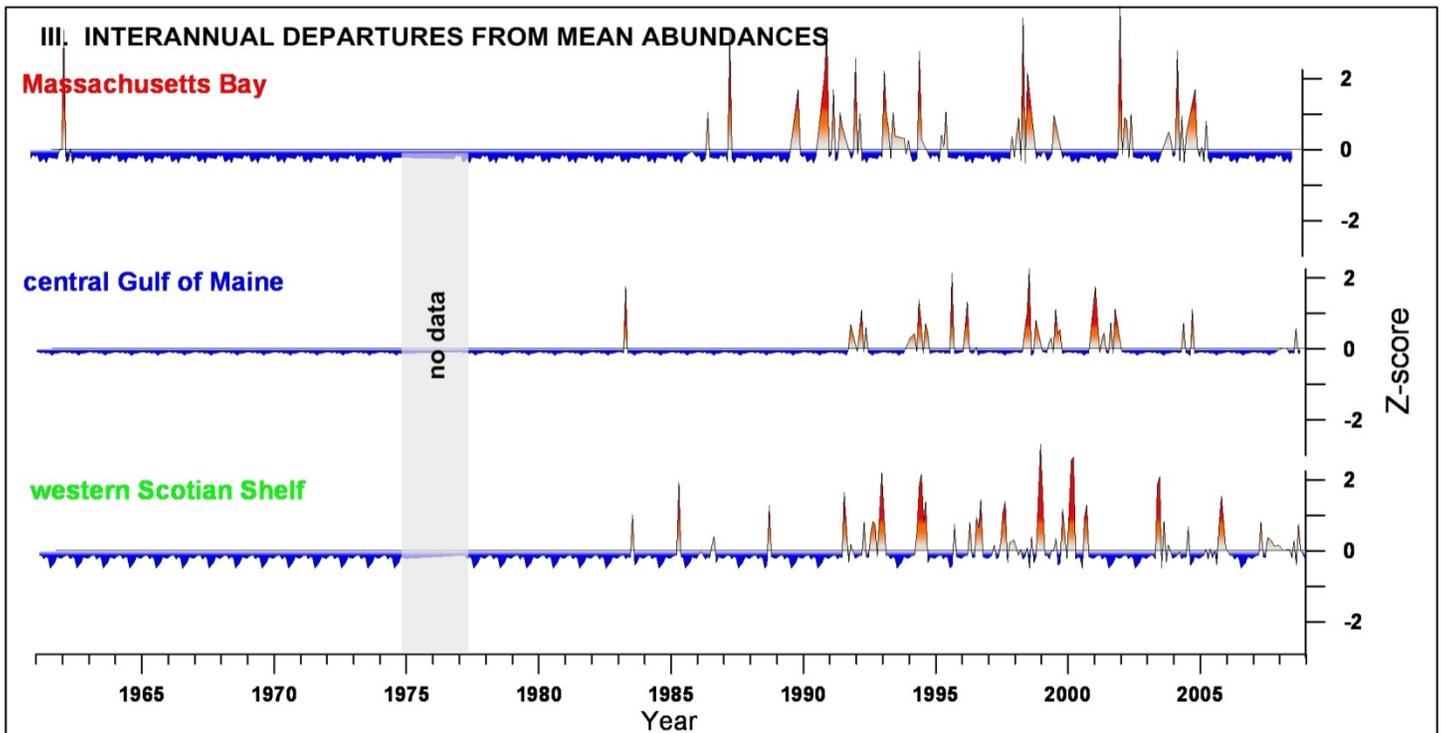


Figure 35 (cont). Decapoda (not Brachyura) larva variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

The decapods are an order of crustaceans whose members include many groups that are harvested commercially (e.g., lobster, shrimp, and crayfish). The infraorder Brachyura (true crabs) is excluded from the taxon reported here. Most decapods have retained a planktonic larval phase that bears little resemblance to the adult. The four larval stages, distinguished by mode of locomotion are nauplius, protozoa, zoea, and postlarva. During some seasons, decapod larvae can be major component of zooplankton biomass and play a significant role in food web dynamics.

Mean concentrations were located in Massachusetts Bay and over the western Scotian Shelf, with zero, or near zero abundances in the central Gulf of Maine after April. In Massachusetts Bay near-zero values prevailed from January-April and peak values occurred from late June to early July. Values declined rapidly by November. On the western Scotian Shelf the taxon was present in low numbers from January-June, peaked from July to mid-September over a larger time/space area than the Massachusetts Bay peak. Western Scotian Shelf values also declined after November, but remained slightly above zero through the end of the year.

Seasonality in Massachusetts Bay resembled the means during the 1960s. From the mid-1980s to the end of the series the period of high abundance was much lengthened. The productive part of the season in the central Gulf of Maine changed from non-existent prior to 1980, to much longer thereafter. On the western Scotian Shelf the variation of seasonality is similar to the central Gulf of Maine. A latening trend of the day of annual maximum occurred in all sections throughout the series.

The monthly departures for the three transect sections mirrored the variations of seasonality.

Tortanus discaudatus, (I.C. Thompson and A. Scott in Herdman Thompson & Scott, 1998), c. 1-6.

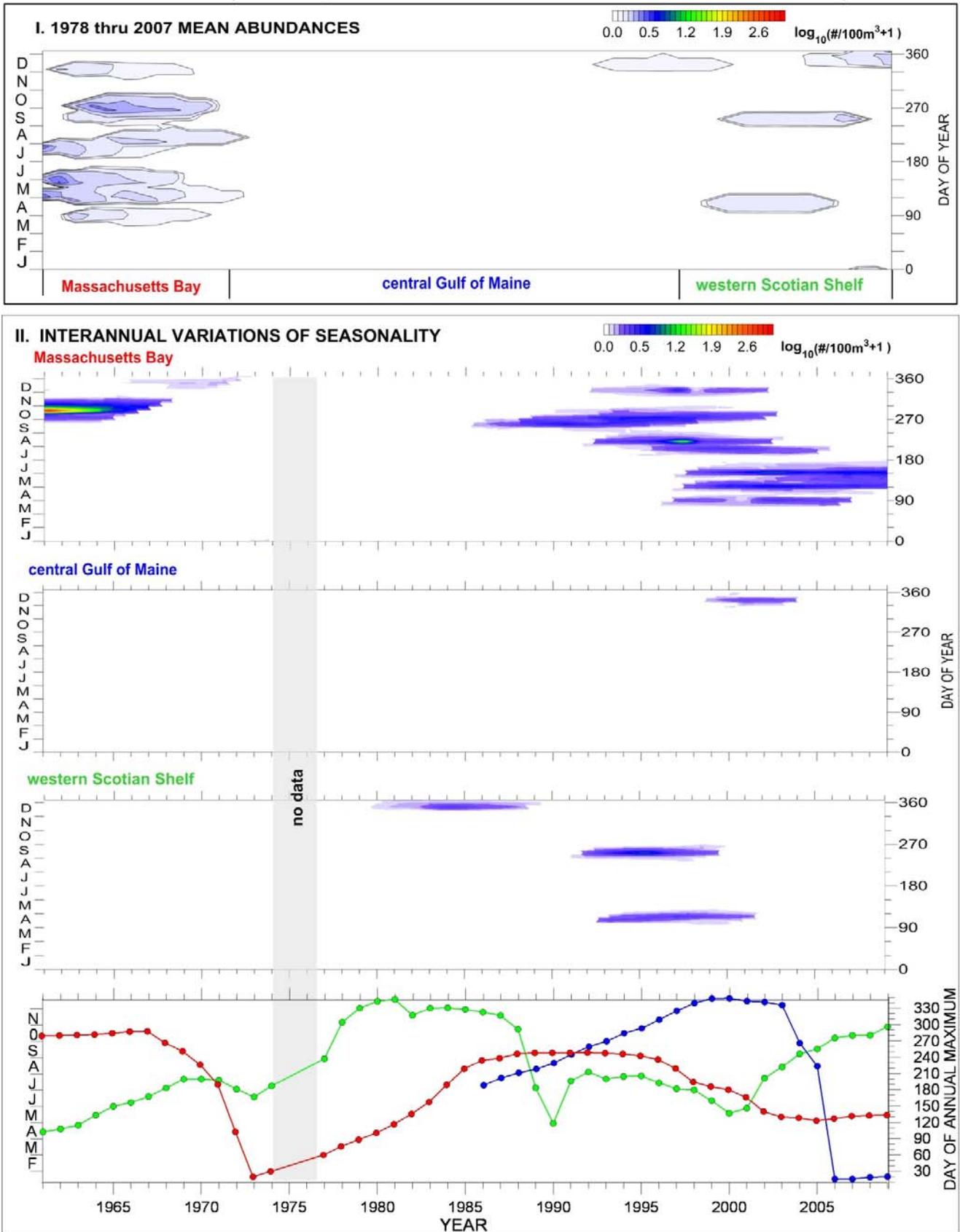


Figure 36. *Tortanus discaudatus* c.1-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

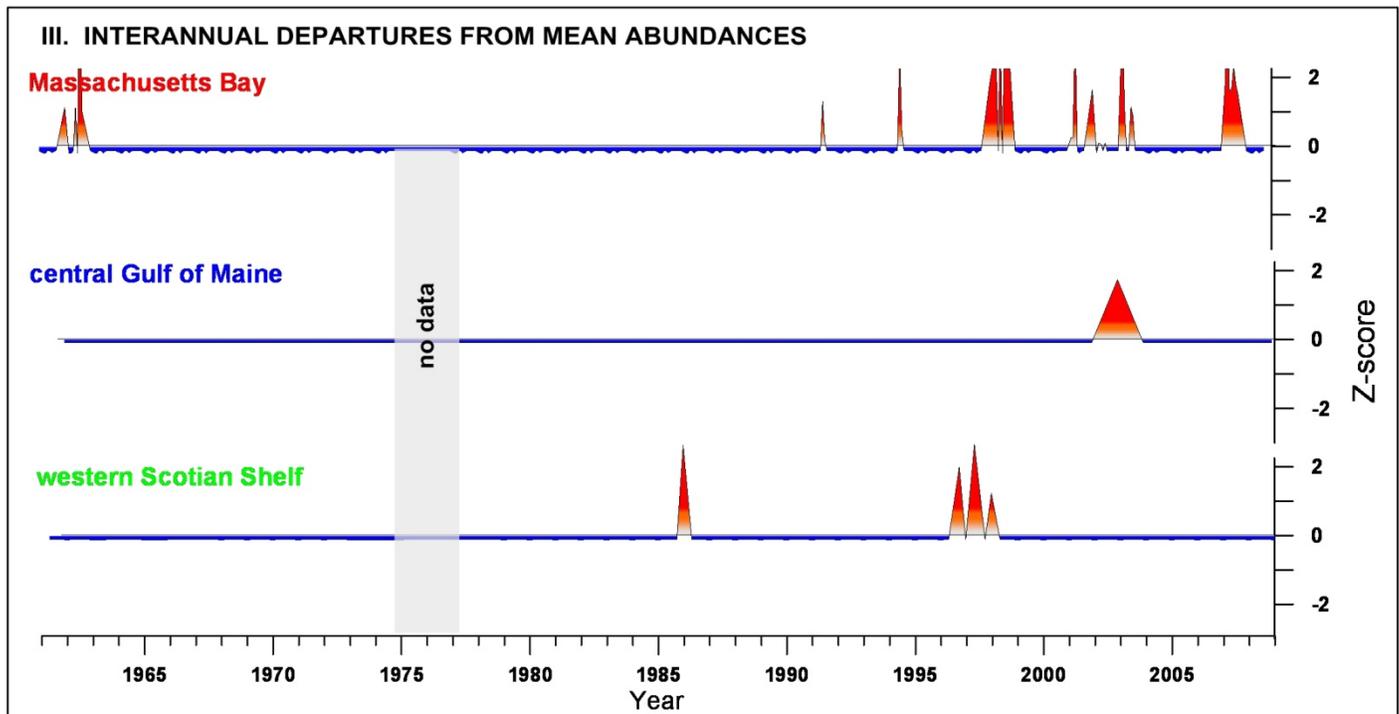


Figure 36 (cont.). *Tortanus discaudatus* c.1-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Tortanus discaudatus is a highly predaceous, neritic copepod occurring mainly in subarctic waters of the North American east and west coasts. It is a non-visual predator that actively darts to encounter and catch copepod nauplii and copepodites. It is not usually captured in large numbers, but it likely has an important role in coastal communities.

Mean concentrations of this taxon were located in Massachusetts Bay from mid-March to mid-December as separated pulses centered in late March, late May, July, late September, and early December. *T. discaudatus* was all but absent in the central Gulf of Maine. Separated pulses were seen on the western Scotian Shelf in late April-early May, September, and December. Values were lower here than in Mass Bay.

Seasonality seems to be closely tied with levels of abundance and with the years chosen for the base period.

Positive anomalies occurred in Massachusetts Bay in the early 1960s, and not again until 1992. Subsequent highs occurred in 1994, 1997-1998, 2001-2003, and 2007. The sole positive departure in the central Gulf of Maine occurred during 2006-2008. The western Scotian Shelf was below average except for large positive anomalies in 1985 and 1996-1998.

Candacia armata, (Boeck, 1872), copepodite stages 5-6.

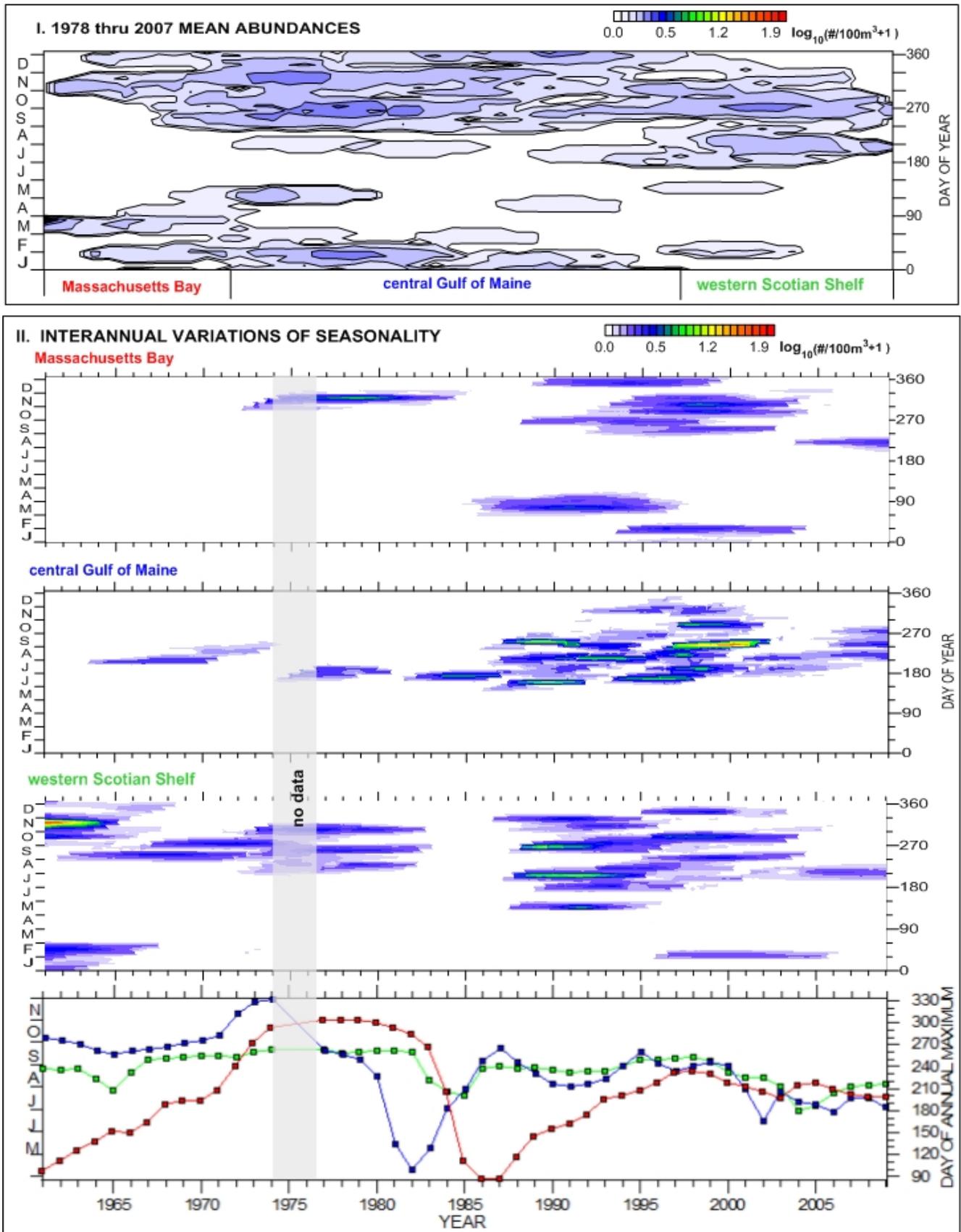


Figure 37. *Candacia armata* c. 5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

Candacia armata, (Boeck, 1872), copepodite stages 5-6

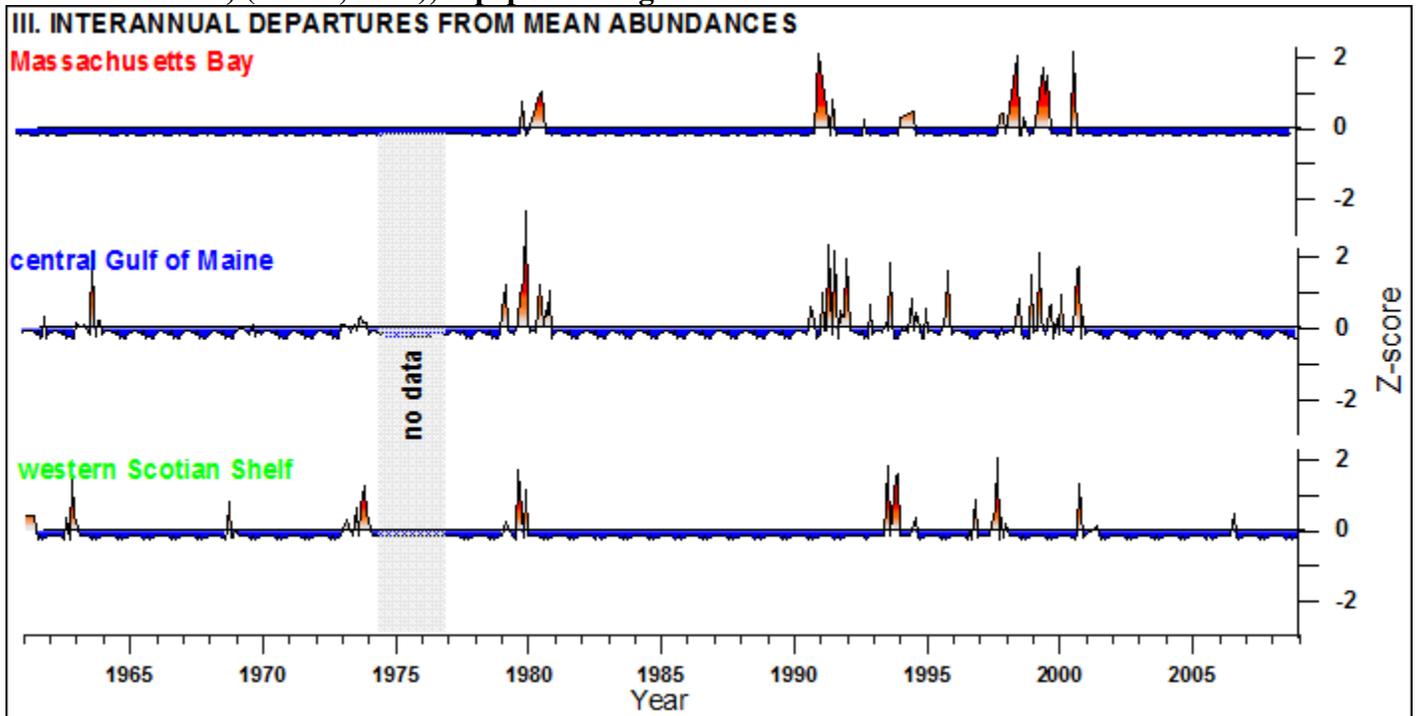


Figure 37 (cont.). *Candacia armata* c. 5-6 variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Candacia armata is an oceanic copepod that can be numerous in shelf waters when offshore water is advected inshore. It occurs throughout the Atlantic Ocean and is routinely used in the North Sea as an oceanic indicator species to track strong inflow into the region. It has been described as a carnivorous copepod that actively pursues its prey.

Mean abundances in January appeared to be connected to the previous year's production, where they occurred in Massachusetts Bay and the central Gulf of Maine. By February they displayed highest abundances in the central Gulf of Maine and also appeared in portions of the western Scotian Shelf. During April, they were present only in Massachusetts Bay, and in May over the outer Massachusetts Bay with a patch in the central Gulf of Maine. Except for a small patch on the western Scotian Shelf, late spring appeared to be the annual low. An increase in abundance began in July on the western Scotian Shelf, and across most of the transect by August with various peaks, the highest being over the western portion of the central Gulf of Maine in September. High values continued through the end of the year, with diminishing ones at the transect ends.

Two seasonality features were worthy of note: 1) the early- to mid-1960s earlying of the day of annual maximum in all three transect sections, and the convergence of this metric in the late 2000s.

Positive departures in the central Gulf of Maine occurred in 1963 and on the western Scotian Shelf in 1961-1962. After 1977 the three transect sections display similar periods of positive anomalies, namely the early 1980s, and early 1990s to early 2000s.

All Taxa, all stages.

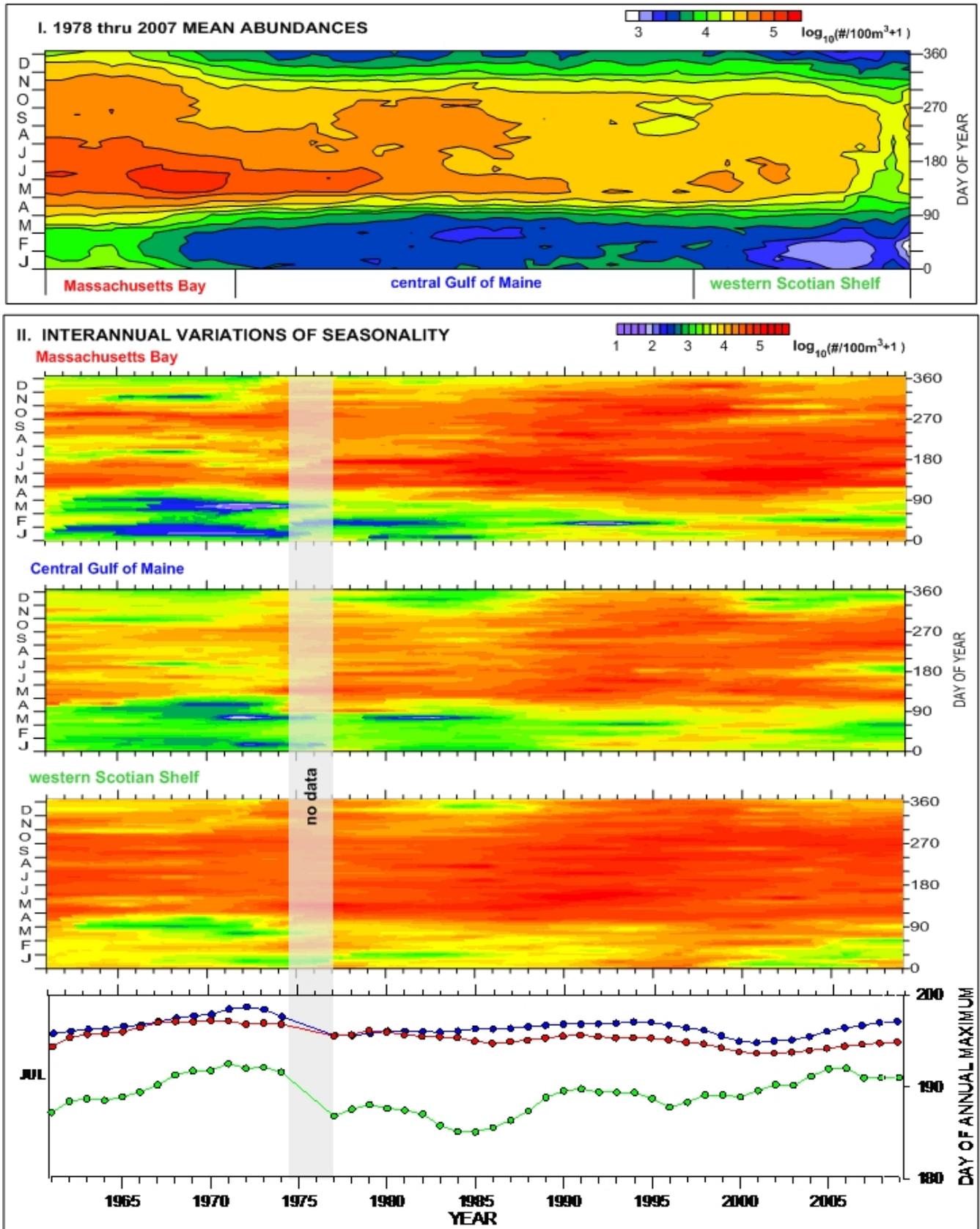


Figure 38. All taxa, all stages, variations along the Gulf of Maine Continuous Plankton Recorder transect.

All Taxa, all stages

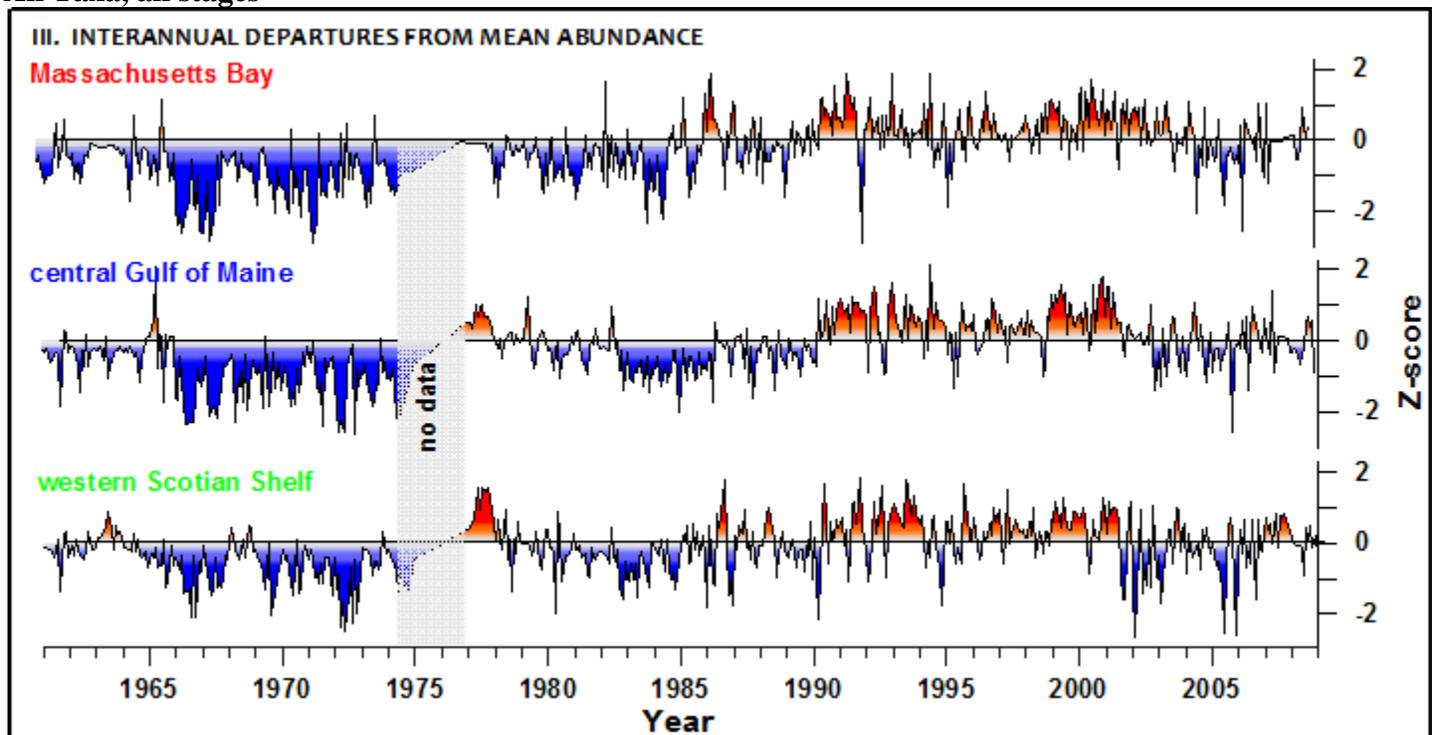


Figure 38 (cont.). All taxa, all stages, variations along the Gulf of Maine Continuous Plankton Recorder transect.

IV. COMMENTS

Mean abundances of all taxa and stages combined lie below approximately 3.8 log₁₀ units (with the exception of the western Massachusetts Bay until March). A rapid abundance increase in March and April leads to annual high values extending to nearly November along the entire transect. Highest annual abundances occur over the western half of the transect, the highest occurring from May to August in eastern Massachusetts Bay. A fall decrease begins in October on the Scotian Shelf, mid-November in Massachusetts Bay, reaching annual low values during December.

A general broadening of the period of high abundances can be seen from 1961 to 2007 in all sections of the Gulf of Maine. This is particularly evident from the period 1990 through early 2000, but continued through the end of the series.

Changes through the series for the day of the annual maximum abundance for the Massachusetts Bay and central Gulf sections were minor, and the patterns for the two sections were quite similar. This timing on the western Scotian Shelf was relatively more variable, with earlier peaks in the early 1960s, late 1970s-1990. Later peaks occurred from the later 1960s to mid-1970s and again around 2005.

Monthly abundance departures from the baseperiod means were negative, with only very brief exceptions, for all three sections from 1961 through the late 1980s. This is followed by a period of positive anomalies across the transect until about 2003 when negative departures prevailed until close to the end of the series.