# Fluctuation in the distribution of the scyphomedusa *Pelagia noctiluca* (Forskål) in the Adriatic

Zooplankton
Medusae *Pelagia*
Unusual occurrence
Intermediate Levantine water
Fluctuation

Zooplancton
Meduse *Pelagia*
Apparition exceptionnelle
l 'eau intermédiaire levantine
Fluctuations

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ABSTRACT

An unusual distribution and high population density of *Pelagia noctiluca* medusae have been noted in the Adriatic from 1977-1981 and some potential explanations of this phenomenon are discussed. This phenomenon has been linked to cyclic fluctuation in Intermediate Levantine water circulation in the Adriatic. Some parallels have been found in the fluctuations in the Mediterranean and North-East Atlantic.

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RÉSUMÉ

Les fluctuations dans la propagation de la scyphoméduse *Pelagia noctiluca* (Forskål) dans l'Adriatique

Il a été constaté une inhabituelle propagation — avec une densité de population très élevée — de la méduse *Pelagia noctiluca* dans l'Adriatique entre 1977 et 1981. Les résultats des études fournissent les explications probables à ce phénomène, qui peut être rattaché aux fluctuations dans la circulation de l'eau intermédiaire levantine en Adriatique. Des points communs ont été relevés dans les fluctuations en Méditerranée et dans l'Atlantique du Nord-Est.

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## INTRODUCTION

The increased abundance of the scyphomedusa *Pelagia noctiluca* along the Adriatic coast during the 1977-1980 period, especially in the North Adriatic, has elicited interest not only among marine biologists, but also among tourist organisations and fishermen (Malej, 1981; Rottini-Sandrini, Stravisi, 1981; Vučetić, 1982). Thousands of bathers have required medical help after being injured by stinging medusae, as have been fishermen during trawling operations (Maretić *et al.*, 1980). The size of any population depends on environmental circumstances and the physiology of the organisms concerned together with the populations history. Regular oscillations in populations can be induced by predation as well as by physiological interactions within the population. It is quite apparent that fluctuations in numbers of *Pelagia noctiluca* occur, but it is not easy to determine whether they are due to the environment or are in some degree under intrinsic physiological control. The nature of some potential explanations, especially for the Adriatic, will be discussed here.

## OCCURRENCE OF THE *PELAGIA* IN THE ATLANTIC

The distribution of *Pelagia noctiluca* as a subtropical species in the Atlantic is not constant. Swarms of *Pelagia* may often be seen in the open sea, where they appear to be most abundant and form wind-rows. Swarms also occur in shallow water and in estuaries (Cole, 1952; Kramp, 1924; 1961; Russell. 1970).

It is very abundant in the Bay of Biscay, where it is frequently carried into the mouth of the Englich Channel and northwards along the western coasts of Ireland and Scotland (Kramp, 1961). It is an important element of the " Lusitanian " plankton carried to Northern Scotland where numbers increased in June 1953, and fishing operations west of Shetland were hindered by early November (Fraser, 1955). In late August 1952 the R. V. Discovery II observed great numbers northeast of the Azores (Hardy, 1958). By the 1966 season, few or no *Pelagia noctiluca* were observed in the northern North Sea, but the largest populations on record were reported from the Western part of the English Channel where they reproduced (Russell, 1967). From there *Pelagia* may have extended to the Texel lightship where they were noted (Baan, 1966).

Cushing and Dickson (1976) felt that the appearence of *Pelagia* in the English Channel occurred when the " Russell cycle " began its reversal. This cycle is connected with profound changes in the ecosystem that occurred between 1925-35 and reversed between 1965-1979 (Cushing, Dickson, 1976; Southward *et al.*, 1975; Southward, 1980).

## OCCURRENCE OF *PELAGIA NOCTILUCA* IN THE MEDITERRANEAN

Lo Bianco (1888, *in* Kramp, 1924) reported mature specimens in the Bay of Naples throughout the year, where they were particularly numerous in winter. Ephyrae were in greatest abudance from November to March.

In 1889 (p. 464) he noted that the medusa has become very scarce in the bay in later years " for no obvious reason ". Mayer (1910) wrote that this medusa was sometimes abundant during summer in the Mediterranean, although rare large specimens could also be seen in winter. A pattern of local abundance for several successive seasons and then an absence for years has been established. " For many years it was all but unknown in the Bay of Naples but since 1900 it has been one of the commonest Scyphomedusans in the region ". Kramp (1924) mentioned its appearance along the Mediterranean coast especially during the winter and spring.

During zooplankton research from February 1968-to September 1969 in the North-western Mediterranean Sea, Franqueville (1971) noted the presence of *Pelagia noctiluca* in spring 1969 (April-May) in a layer from 280-350 m (station 45, collected with an open net).

## *PELAGIA* DISTRIBUTION IN THE ADRIATIC

For the last 50 years these jellyfish apparently have been relatively uncommon along the northern and Central Adriatic coast. Rottini-Sandrini and Stravisi (1981) wrote that « for the first time in 1977-1980 many swarms of *Pelagia noctiluca* have been noticed in the northern Adriatic with maximum intensity along the coast of Istria and in the Gulf of Trieste from April-May to October-November ". During this 1977-1981 period, the appearance of this jellyfish on shores with thousands of bathers resulted in extensive publicity, when these summer tourists asked for medical help after being stung by this scyphomedusan (Maretić *et al.*, 1980). Previous records in the North Adriatic are scattered but include findings near Trieste (Neppi, 1922), along the Istrian coast near Brioni Island in summer 1913 (Stiasny, 1921), and south near Senj in July 1895 (Babić, 1913). The most numerous information for the whole Adriatic and especially for the Central part or south Dalmacia was from Babić (1913). He noted that *Pelagia noctiluca* was a species of the deep sea, found often only in deep Adriatic pits. He observed many in June 1910 and May 1911 after periods of southerly winds in the waters surrounding the Island of Vis.

After the above findings in the period from 1895-1914, *Pelagia* was not mentioned in any plankton paper until 1977. After 1977 an enormous quantity of adults has been seen from Otranto to Trieste bay, as well as young stages-especially from May to September (Malej, 1981; Rottini-Sandrini, Stravisi, 1981; Rottini-Sandrini, 1982; Vučetić, 1982; Rottini-Sandrini, Vučetić, in press).

The appearance of *Pelagia noctiluca* in the Adriatic in earlier years (before 1977) never presented a problem to the human population. During the 1900-1920 period, bathing in the sea was probably less popular and bathers were more protected by clothing. However the absence of any earlier mention of stinging may indicate that : *a*) the medusae did not appear in such dense swarms; *b*) the medusae sting more; or *c*) humans have become more sensitive. Answers to questions regarding the irregular appearance of *Pelagia* in the Adriatic area are perhaps the key to understanding this phenomena. Are we seeing : *a*) fluctuations in the distribution; or *b*) fluctuations in the population density ?

## DISCUSSION

The irregular appearance of *Pelagia noctiluca* seen in the coastal areas of the Eastern Atlantic and Mediterranean has now been established in the North Adriatic. In connection with this we have tried to answer some questions :

Where is this species permanently present ? Does it show strong periodic fluctuations in its autochthonous region ? Does it regularly respond to some cyclical fluctuations in the environment (hydrographic or biological) or to some intrinsic (physiological) factor ?

A comparison of all density data for *Pelagia* shows that the autochthonous region of this species is around the Azores (Broch, 1933; Hardy, 1958; Fig. 1). This region appears to be an area of Mediterranean water with higher salinity and temperature then in other parts of the Atlantic (Wüst, 1978). From this zone *Pelagia* may spread to the north (and south) and the fluctuations in the dynamics of these water masses are reflected in both the species distribution and its population density.

High population densities may result from enhanced reproduction in the autochthonous region before trans-

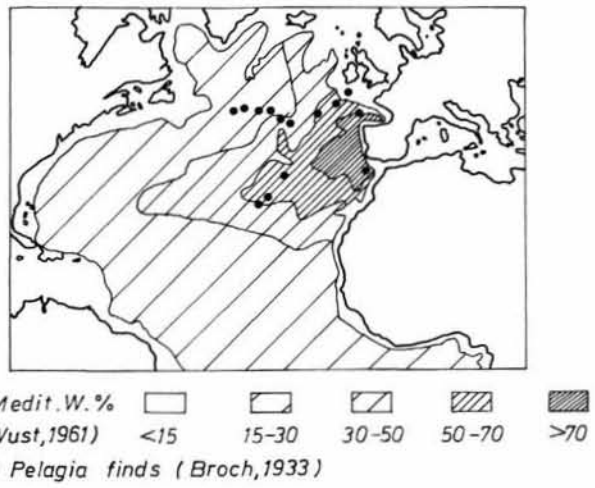


Figure 1

*Spreading of the upper North Atlantic deep water in the core layer (intermediate salinity maximum), represented by the percentage of the Mediterranean component (Wüst, 1978). Occurrence of* Pelagia perla *during the cruise of the « Michael Sars » (from Broch, 1933).*

port to the North, or from increases in population density after transport to these northern areas. The second hypothesis is that after arriving in the North, at an interface area, between unfavorable northern water conditions and the favorable southern waters, *Pelagia* invests much energy in reproductive cells in response to reduced salinity and other conditions linked with polluted coastal waters.

In the Mediterranean Sea, *Pelagia* is probably autochthonous in deep water (Fig. 2) to the east and south of Sicily. Resident populations may also exist in the Tyrrhenian and Ionian seas. Since there have been no systematic surveys of zooplankton in this area, it is not possible to speak about fluctuations in population density for this area.

The " Intermediate Levantine water " circulation must play a very important role in the distribution of this species (Nielsen, 1912; Wüst, 1961). Is it possible that the deep or intermediate Mediterranean waters carry adult medusae to the Atlantic (through Gibraltar), and that with surface inflow of Atlantic waters the ephyra stages return to the Mediterranean, as *Pelagia* was often registered around the Baleares ? After Goy's opinion, this cannot be possible since neither young nor

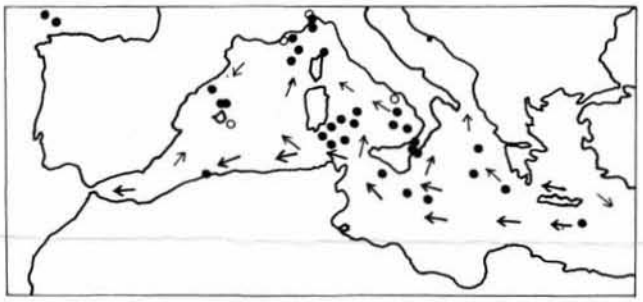

Figure 2

*Finds of* Pelagia noctiluca *(from Kramp, 1924) and Levantine intermediate water circulation (from Wüst, 1961).*

adult *Pelagia* have been found in the strait of Gibraltar during the cruise of October and November 1981 (MEDIPROD) and these are the only observations in the strait (Goy, 1982).

The strongest fluctuation in numbers have been registered in the North Atlantic, North Sea, Gulf of Lyon, Bay of Naples and the Adriatic, where they are not permanently present. These fluctuations may be connected with water mass movements (Le Danois, 1934; Taylor-Stephens, 1980), SST changes (Fieux *et al.*, 1979; Fig. 8, 10), water quality changes (Cushing and Dickson, 1976) or some cyclical phenomenon (Le Danois, 1934; Southward *et al.*, 1975).

A review of the Mediterranean hydrographic data (Sankey, 1973) for the period of Franquevillé (1971) findings of *Pelagia* near Marseille indicates that it arrived during an upwelling of the Levantine Intermediate Water, which was especially visible from spring to late autumn in 1969 (Fig. 5, *in* Sankey, 1973). A similar phenomenon occurred during the same period in the Adriatic in 1969, when there was an advection of intermediate South Adriatic water to the North with a strong influx of Mediterranean water (Buljan, Zore-Armanda, 1976).

As we have many data on the biological response to environmental changes (cycles, periodicity, etc.) for the Adriatic ecosystem, especially in connection with hydrographic characteristics of this land-locked sea, we shall try to explain the distribution of *Pelagia* in connection with these fluctuations in the distribution of water masses (Vučetić, 1973).

In advection years warmer (14 °C-15 °C) and saltier (up to 38.8-9 $^{o}/_{oo}$) waters spread to the North Adriatic. This influx was especially strong in 1876; 1910-1914 period, 1930, 1939, 1948-1949, 1957 and 1969 (Buljan, Zore-Armanda, 1976) and for the last 4 years (1977-1981; Fig. 3).

These conditions may have allowed *Pelagia* to be active, rather then sinking to the bottom as they do in years without such influxes, or in the cool (10-11 °C) water in the winter. In this warmer surface layer (14 °C) they can continue their biological cycles as Rottini-Sandrini (1982) has shown experimentally.

Before the recent ingression of *Pelagia* (1977 onwards), it had been generally absent from the Adriatic since the period 1895-1914. Because the recent invasion was associated with the abnormal presence of high saline water in winter (1976), the presence of the animal may indicate difference of water transport at long intervals of time. Buljan (1953), Regner-Gačić (1974) and Županović (1968) have referred to short and long term cycles in the Adriatic ecosystem. It may well be that the invasion of the Adriatic by *Pelagia* reflects the long term periodicities which occur in marine ecosystems. Ottestad (1942; 1960) has shown that the variations in cod catches at Lofoten may reflect long term periodicities. If such periodicities in abundance of *Pelagia* are real, there would be no need to attribute its appearance in the Adriatic to local pollution. Other evidence of the influence of influxes in the Adriatic are, the occurrence of

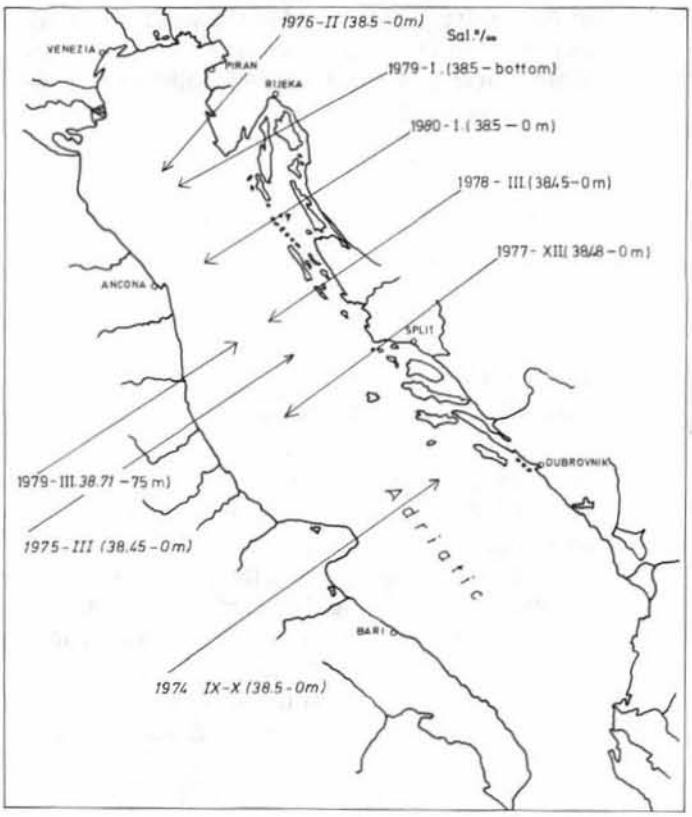


Figure 3

*Salt water advection in the North Adriatic in the surface layer in the period 1974-1980.*

whales, sharks and rare cephalopods from the open Mediterranean, and some movement of organisms from the South to the North of sardinella, *Sagitta decipiens* and some copepods (Vučetić, 1970). This influx is also indicated by a general increase in productivity of the sea and " good " fisheries years.

Inflow of intermediate and surface water in the deep south Adriatic in winter is continuous but there are large differences from year to year in the intensity of this advection; sometimes southern waters of high salinity can be detected in the most northern water of the Adriatic (Zore-Armanda, 1968; 1974). These findings in the Adriatic are similar to those in other coastal Mediterranean areas (Majorca, Gulf of Lyon, Naples, Messina). They probably depend on changes in water mass dynamics due to the distribution of deep Intermediate Levantine water (Fieux *et al.*, 1979; Lacombe *et al.*, 1981; Garzolli, Maillard, 1977). One of the years with a stronger Mediterranean influence in the Adriatic was 1969 (Buljan, Zore-Armanda, 1976). The warmer and more saline Intermediate Levantine water arrived in the North and at the surface in the Adriatic. Something of the same sort also 1969 appeared in the Gulf of Lyon (Sankey, 1973).

After 1966 in the Atlantic, some climatic changes may have influenced water mass dynamics, especially shown by the " reversed Russell cycle " (Cushing, Dickson, 1976; Southward *et al.*, 1975; Southward, 1980; Taylor, Stephens, 1980). The strong influence of the ingression of southern waters from the Central to the North Atlantic brought *Pelagia* to the North Atlantic and to the North Sea (from the North or through the Channel).

High population densities may be produced by unsuitable hydrography in the place of arrival or by the influence of coastal waters of reduced salinity and increased quantities of toxicants. The potential effects of increased concentrations of pollutants have been demonstrated experimentally (Stebbing, 1981 *a*, *b*). Stebbing (1981 *a*) found in a hydroid that gonozooid frequency increased as a response to reduced salinity and other unfavourable changes in the water chemistry and a hormesis-stimulation of colony growth by copper, cadmium and other toxicants (1981 *b*). In the case of *Pelagia* differences in water mass quality may result in a great population density of *Pelagia* at the boundary of two different water bodies.

## CONCLUSION

Fluctuations in the distribution and the population densities of *Pelagia* have been shown to appear at the same time as the long term environmental changes in water mass dynamics, especially of the Intermediate Levantine water in the Mediterranean and the Adriatic.

Observations here show promise for the prediction of population fluctuations and suggest the relevance of previously proposed periodicity in the ecosystem such as that put forward by Le Danois (1934) regarding Atlantic-water " transgressions " and compared by Buljan (1953, Fig. 72) with the " ingression " or influx of Levantine Intermediate water in the Adriatic.

The stronger appearance of *Pelagia* seems to have begun in the Atlantic in 1966, in the Mediterranean in 1969 and in the Adriatic in 1977. These dates are signi-

ficant in the reversal of the Russell cycle (Southward, 1980).

From the data reviewed above and other analyses available (Županovic, 1968 ; Fieux *et al.*, 1979 : Lacombe *et al.*, 1981 ; Sankey, 1973) in the last decade it is clear that there has been a stronger circulation in the Mediterranean and in the Adriatic from the South.

These changes in population distribution and density may be " natural " fluctuations produced by climatic changes, but the anthropogenic influence of pollution may also be a contributing factor, if somewhat unlikely since the animals appeared early in the century. Pollutant-induced changes may only be observed in less saline and polluted waters under present-day conditions.

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