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Microscale processes in the ocean: why are they so important for ecosystem functioning?

Laurent SEURONT*

Abstract : Turbulence has widely been regarded as being a homogeneous process. Turbulence effects on ecosystem fluxes have been estimated from the mean values of turbulent kinetic energy dissipation rates. However, turbulent processes are highly intermittent. Making use of multifractal concepts, this study shows that the intermittent nature of microscale turbulence results in (i) an increase in the rate of nutrient fluxes around non-motile phytoplankton cells (6-62%), (ii) a decrease in the physical coagulation of phytoplankton cells (25-48%) and in the subsequent phytoplankton aggregate volumes (22-41%), and (iii) a decrease of the turbulence contribution to predator-prey encounter rates (25-50%).

Key words : *microscale turbulence, intermittency, nutrient fluxes, physical coagulation, predator-prey encounter rates, phytoplankton and zooplankton dynamics, matter fluxes*

1. Introduction

There has been a long lasting interest among plankton ecologists to quantify the effects of microscale turbulence on both phyto- and zooplankton trophodynamics. Knowledge of such processes (and their space-time variability) is a prerequisite for understanding trophic interactions in the pelagic environment and the functioning of plankton food webs. Turbulence has thus been shown to play a salient role in determining the rates of nutrient fluxes around phytoplankton cells (ESTRADA and BERDALET, 1997), the formation of phytoplankton aggregates (JACKSON, 1994), the subsequent vertical matter fluxes in the ocean (KIORBOE *et al.*, 1990), and the predator-prey encounter rates (ROTHSCHILD and OSBORN, 1988).

Microscale turbulent processes have been widely regarded as homogenizing factors. Modeling of nutrient fluxes (LAZIER and MANN, 1989; KARP-BOSS *et al.*, 1996), aggregation processes (KIORBOE *et al.*, 1990), predator-prey encounter rates and studies of zooplankton

trophodynamics (e.g. KIORBOE and SAIZ, 1995; CAPARROY and CARLOTTI, 1996) have thus implicitly assumed that microscale zooplanktonic and phytoplanktonic distributions are statistically homogeneous in space and time.

However, an intriguing aspect of microscale turbulence is that it may generate microscale patchiness rather than uniformity (JIMENEZ, 1997). Instantaneous gradients of scalars such as temperature, salinity or nutrients are indeed the greatest at scales similar to the Kolmogorov microscale, i.e. the viscous scale where viscosity effects cannot be neglected and start to smooth out turbulent fluctuations (SANFORD, 1997). In other words, this form of variability, or "intermittency", reflects heterogeneous distributions with a few high density patches and a wide range of low density patches (Fig. 1), and has now widely been characterized in terms of physical, chemical and biological structures. More specifically, these fluctuations have been analyzed in the multifractal framework (PASCUAL *et al.*, 1995; SEURONT, 1997, 1999a, b; SEURONT *et al.*, 1996a, b, 1999, 2001a, b), with statistical tools that are more general than standard methods, such as spectral techniques, which only provide limited information on the statistics of the process due to their intrinsic

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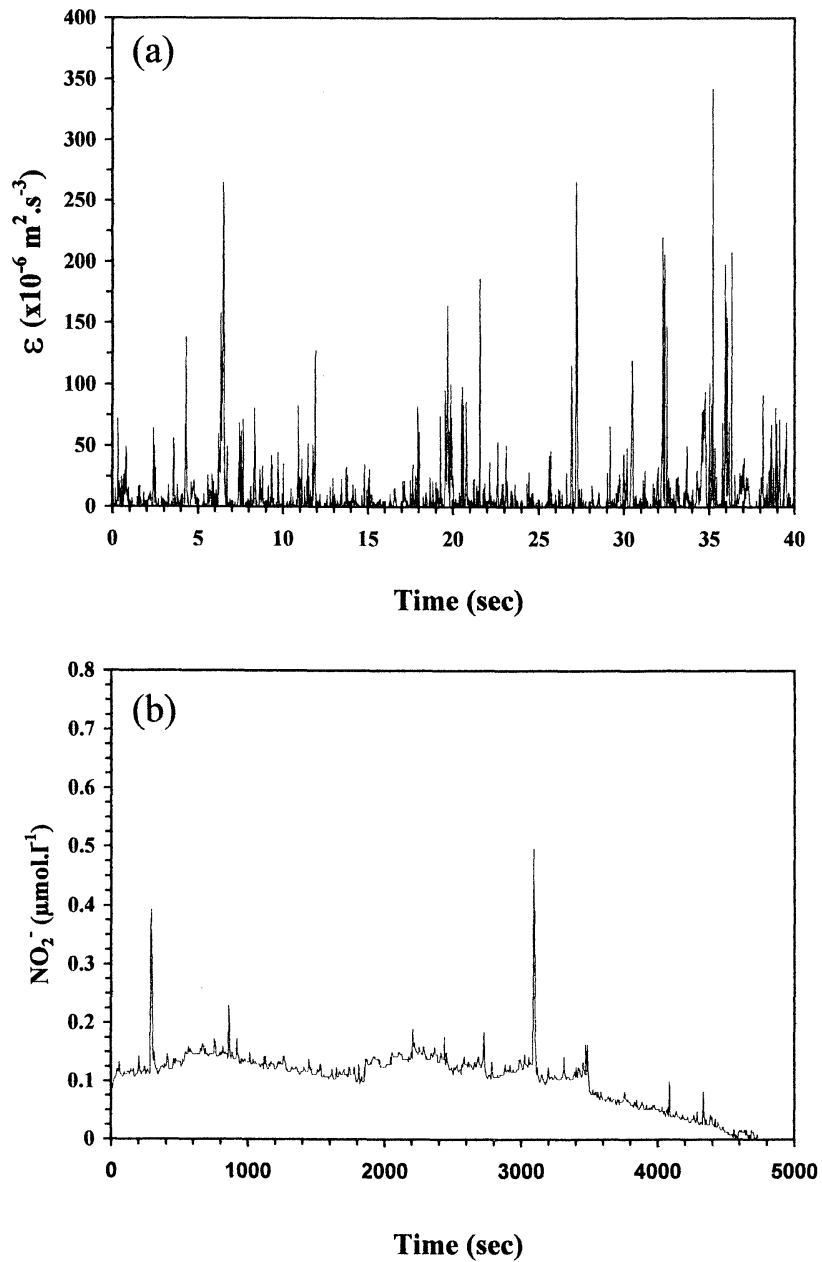


Fig. 1. Samples of (a) the pattern of the turbulent kinetic energy dissipation rates estimated from grid generated turbulent velocity fluctuations recorded with a hot wire velocimeter (redrawn from SEURONT *et al.*, 1999), and (b) the high frequency distribution of nitrite NO_2^- recorded in the Eastern English Channel (redrawn from SEURONT *et al.*, 2001a). Turbulent kinetic energy dissipation rates and nitrite distributions exhibit at all scales sharp fluctuations called intermittency.

links to Gaussian distributions (see e.g. PLATT and DENMAN, 1975; FASHAM, 1978).

As microscale physical processes are of primary interest in plankton ecology (e.g. DAVIS *et al.*, 1991), the question addressed here is whether these specific intermittent physical structures affect marine life and its associated fluxes. To that end, in the present paper I (i) review briefly the formalism developed by SEURONT *et al.* (2001b) to describe the statistical behavior of intermittent turbulent processes, (ii) use this approach to derive simple equations used to estimate the effect of intermittent microscale turbulence on nutrient fluxes around non-motile phytoplankton cells, on phytoplankton cells aggregations, and on predator-prey encounter rates, and (iii) quantify the potential specific effects of intermittent microscale turbulence on these processes.

2. Describing microscale intermittent processes in the ocean

In this paper I only review the main properties of a multifractal field. More details on the use of multifractal algorithms to marine ecology studies, and what can be concluded from their use can be found in SEURONT *et al.* (1999). A main property of a multifractal field is that its fluctuations are not destroyed by smoothing at any scale, until the outer scale of the system is reached. For a given turbulent energy dissipation rate ε , this means that the multifractal field ε averaged over a scale l will have a scale-dependent value denoted as ε_l , or as ε_λ . Here we introduce a non-dimensional scale ratio λ ($\lambda = L/l$), which is the ratio between an external length scale L and a targeted length scale within the inertial subrange, i.e. $L \leq l \leq l_K$ where the Kolmogorov length scale is expressed as l_K [see SEURONT *et al.* (1999) for further details]. We assume in this analysis $\lambda \gg 1$. The scale-dependent multifractal field ε_λ can be described by its probability distribution, or equivalently, by its statistical moments $\langle\langle \varepsilon_\lambda^q \rangle\rangle$, where we consider any $q \geq 0$. These moments can be scaled with the scale ratio λ , as (SEURONT *et al.*, 1999):

$$\langle\langle \varepsilon_\lambda^q \rangle\rangle = \varepsilon_0^q \lambda^{K(q)} \quad (1)$$

where ' $\langle\langle \cdot \rangle\rangle$ ' indicates statistical or spatial

averaging, $\varepsilon_0 = \langle \varepsilon \rangle$ is the mean of the multifractal process ε_λ , and $K(q)$ is a scale-invariant moment function which is convex and satisfies $K(0) = 0$ and $K(1) = 0$. The knowledge of $K(q)$ fully describes the statistics of the process, in an equivalent manner as the probability distribution. The second moment $\mu = K(2)$ is usually denoted as an intermittency parameter. In the following we consider a continuous range of values of $q \geq 0$. It should be noted here that Eq. (1) is valid only for scales belonging to the inertial subrange, thus for $l \leq \lambda \leq \Lambda$, where $\Lambda = L/l_K$ is the maximum scale ratio, between the larger outer scale and the Kolmogorov scale l_K .

Subsequently, Eq. (1) can be used to evaluate the average of any polynomial function $f(\varepsilon_\lambda)$ of the multifractal field ε_λ as (SEURONT *et al.*, 2001b):

$$f(\varepsilon_\lambda) = \sum_{p=0}^N a_p (\varepsilon_\lambda)^p \quad (2)$$

where a_p are constants, and p the polynomial order of the function $f(\varepsilon_\lambda)$. Averaging the function finally leads to:

$$\langle f(\varepsilon_\lambda) \rangle = \sum_{p=0}^N a_p \varepsilon_0^p \lambda^{K(p)} \quad (3)$$

This equation will be used in the following section.

3. Significance of microscale intermittency

To evaluate the potential significance of intermittency for nutrient fluxes around non-motile phytoplankton cells, phytoplankton cells aggregations, and predator-prey encounter rates we need to compare the conventional view of homogeneous turbulence and the effects of intermittency.

3.1 Intermittent turbulence and nutrient fluxes around phytoplankton cells

Following KARP-BOSS *et al.* (1996), the increased rate of nutrient flux due to turbulence around non-motile phytoplankton cells can be directly estimated using the Sherwood number, Sh , as:

$$Sh_1 = 1 + 0.29 \frac{r}{(D\nu^{-1/2})^{1/2}} \cdot \frac{1}{\varepsilon_0^{1/4}} \quad \text{for } r < l_B \quad (4)$$

$$Sh_2 = 0.55 \frac{r}{(D\nu^{-1/2})^{1/2}} \cdot \frac{1}{\varepsilon_0^{1/6}} \quad \text{for } r > l_B \quad (5)$$

where r is the cell radius (m), D the diffusivity ($D = 10^{-9} \text{m}^2 \cdot \text{s}^{-1}$), ε_0 the mean turbulent energy

dissipation rate ($\text{m}^2 \cdot \text{s}^{-3}$), ν the kinematic viscosity ($\nu = 10^{-6} \text{m}^2 \cdot \text{s}^{-1}$) and l_b the Batchelor microscale, the scale of the smallest variations in the ambient nutrient field. One may note here that the Batchelor microscale l_b is smaller than the Kolmogorov microscale l_K following $l_K = l_b (D/\nu)^{1/2}$.

Now let the turbulent kinetic energy dissipation rate ε be a multifractal variable ε_λ characterized by the scaling moment function $K(q)$ defined above, and by its mean $\varepsilon_0 = \langle \varepsilon_\lambda \rangle$. Consider the average Sherwood numbers Sh_1' and Sh_2' associated to the intermittent (multifractal) variable ε_λ and defined as $Sh_1' = \langle Sh_1(\varepsilon_\lambda) \rangle$ and, $Sh_2' = \langle Sh_2(\varepsilon_\lambda) \rangle$ when $r < l_b$ and $> l_b$, respectively. Using Eq. (3), Eqs. (4) & (5) can thus be rewritten as:

$$Sh_1 = 1 + 0.29 \frac{r}{(D\nu^{-1/2})^{1/2}} \cdot \frac{1}{\varepsilon_0^{1/4} \lambda^{K(1/4)}} \quad \text{for } r < l_b \quad (6)$$

$$Sh_2' = 0.55 \frac{r}{(D\nu^{-1/2})^{1/2}} \cdot \frac{1}{\varepsilon_0^{1/4} \lambda^{K(1/6)}} \quad \text{for } r > l_b \quad (7)$$

One needs to be aware that $\lambda \gg 1$ while $K(1/4) < 0$ and $K(1/6) < 0$, therefore $1/\lambda^{K(1/4)}$ and $1/\lambda^{K(1/6)}$ act as enhancing factors in Eqs. (6) & (7) yielding $(Sh_1'/Sh_1) > 1$ and $(Sh_2'/Sh_2) > 1$. This shows that using a mean value of the turbulent kinetic energy dissipation rate ε_0 instead of the multifractal distribution ε_λ leads to underestimate the turbulence contribution to the rates of nutrient fluxes around phytoplankton cells, whatever their size may be.

In order to quantify this difference, one needs to estimate the intermittent enhancing factors (Sh_1'/Sh_1) and (Sh_2'/Sh_2) due to $1/\lambda^{K(1/4)}$ and $1/\lambda^{K(1/6)}$ in Eq. (6) & (7) using realistic values of λ , $K(1/4)$ and $K(1/6)$. The inertial subrange scale ratio λ is increasing with increasing intensities of turbulence, and can be reasonably regarded as ranging between 10^2 and 10^5 (e.g. GREGG, 1999). The scale-invariant moment exponents $K(1/4)$ and $K(1/6)$ have been estimated from high resolution shear vertical profiles recorded in tidally mixed coastal waters following SEURONT *et al.* (1999) as $K(1/4) = -0.053 \pm 0.005$ and $K(1/6) = -0.042 \pm 0.004$ (SEURONT and YAMAZAKI, unpublished data). The resulting enhancing factors $(Sh_1'/$

$Sh_1)$ and (Sh_2'/Sh_2) ranges between 1.06 and 1.19, and between 1.21 and 1.62 when $r < l_b$ and $r > l_b$, respectively. That finally leads to consider an increase in the rate of nutrient fluxes around phytoplankton cells due to microscale turbulence intermittency ranging between 6.26% and 19.07% for phytoplankton cells smaller than the Batchelor microscale l_b , and between 21.22% and 61.78% for phytoplankton cells larger than the Batchelor microscale l_b . One may also note that the inertial subrange scale ratio increases with increasing intensities of turbulence. The increase in the rate of nutrient fluxes around phytoplankton cells of any size is thus higher when the intensity of turbulence is high.

3.2 Intermittent turbulence and physical coagulation of phytoplankton cells

Theoretical analyses of particles coagulation processes predict that aggregate formation depends on the probability of particle collision and on the efficiency with which two particles that collide and stick together afterwards (MCCAVE, 1984; JACKSON, 1990). The former is a function of particle concentration, size and the mechanism by which particles are brought into contact, e.g. Brownian motion, shear or the differential settlement of particles. The latter which is not studied in the present paper depends mainly on the physicochemical properties of the particle surface and may vary with the particle type.

Let consider a monospecific phytoplankton cells suspension characterized by a cell radius r (m) and cell concentration C ($\text{cells} \cdot \text{m}^{-3}$). Because all particles are of the same size and density and settle with the same velocity, and because encounters due to Brownian motion is insignificant for particles $> 1 \mu\text{m}$ (MCCAVE, 1984), the only mechanism that may increase the relative velocity between phytoplankton cells and thus bring them to collide is due to turbulent shear and can be expressed as (KIORBOE, 1997):

$$E_1 = 10.4r^3C^2 (\varepsilon_0/\nu)^{1/2} \quad (8)$$

where E_1 is the encounter rate due to turbulence ($\text{encounter} \cdot \text{s}^{-1}$), ε_0 the mean turbulent energy dissipation rate ($\text{m}^2 \cdot \text{s}^{-3}$) and the kine-

matic viscosity ($\nu = 10^{-6} \text{m}^2 \cdot \text{s}^{-1}$).

As previously done in section 3.1, let the turbulent kinetic energy dissipation rate be a multifractal variable ε_λ characterized by the scaling moment function $K(q)$ defined above, and by its mean $\varepsilon_0 = \langle \varepsilon_\lambda \rangle$. Here, E_1 and $E_1' = E(\varepsilon_0)$ are regarded as estimates of average encounter rates, i. e. $E_1 = E(\varepsilon_0)$ and $E_1' = \langle E(\varepsilon_\lambda) \rangle$ when the turbulent energy dissipation rates are regarded as homogeneous and intermittent (multifractal) variables, respectively. In this case, Eq. (8) is rewritten as:

$$E_1' = 10.4r^3C^2 \nu^{-1/2} \varepsilon_0^{1/2} \lambda^{K(1/2)} \quad (9)$$

This finally yields:

$$E_1' = E_1 \lambda^{K(1/2)} \quad (10)$$

and as defined above, $\lambda \gg 1$ and $K(1/2) < 0$, $\lambda^{K(1/2)}$ thus acts as a restraining factor therefore $E_1' < E_1$. Using the values of λ proposed in section 3.1 (i.e. $\lambda \in [10^2, 10^5]$) and $K(1/2) = -0.063 \pm 0.005$ (SEURONT and YAMAZAKI, unpublished data), the factor $\lambda^{K(1/2)}$ ranges between 0.48 and 0.75. Now, taking into account the intermittent nature of microscale turbulence leads to consider a decrease in its contribution to the physical coagulation of phytoplankton cells ranging between 25% and 48%. This decrease is higher when the turbulence levels are high (i.e. the inertial subrange scale ratio is large).

Considering the role played by large particle aggregates in the vertical flux of organic matter in the ocean (GARDNER, 1997; JACKSON and BURD, 1998), I focus the effects of this decrease in encounters due to intermittency on the growth in particle size. It has been shown that the average solid volume of aggregates increases according to the following formula (KIORBOE *et al.*, 1990):

$$V_t = V_0 e^{\alpha [7.8\phi(\varepsilon_0/\nu)^{1/2}/\pi] t} \quad (11)$$

where V_0 and V_t are the average volume of aggregates at time 0 and t , α is the stickiness coefficient (i.e. $\alpha \in [0, 1]$), ϕ is the volume-concentration of cells [$\phi = (4/3) \pi r^3 C_0$]. Introducing the precise statistical distributions of turbulent dissipation rate ε_λ in Eq. (11) instead of its average value ε_0 leads to a decrease in the aggregate average volumes ranging

between 22% and 41% in low and high hydrodynamic conditions, respectively.

3.3 Intermittent turbulence and zooplankton trophodynamics

Following the seminal theory of ROTHSCHILD and OSBORN (1988), KIORBOE and SAIZ (1995) demonstrated that the encounter rate E (encounters. s^{-1}) between plankton predators and preys can be expressed as the sum of the encounter rate due to organism behavior and the encounter rate due to microscale turbulence. The former is a function of particle concentration, swimming speed of predator and prey and perceptive distance of the predator. The latter which I explore here in more details is expressed as:

$$E_2 = C \pi R^2 w \quad (12)$$

where E_2 is the encounter rate due to microscale turbulence, C is the number of preys per unit volume (preys. m^{-3}), R is the perceptive distance of the predator (m), and w ($\text{m} \cdot \text{s}^{-1}$) is the root-mean-square turbulent velocity enhancing the relative motion between predator and prey. The rms turbulent velocity w is directly related to the intensity of turbulence, characterized by a mean value of the turbulent kinetic energy dissipation rate ($\text{m}^2 \cdot \text{s}^{-3}$) following (ROTHSCHILD and OSBORN, 1988):

$$w = 1.9 (\varepsilon_0 d)^{1/3} \quad (13)$$

where d is the separation distance between predator and prey when encounter takes place, i.e. $d = R$ (e.g. VISSER and MACKENZIE, 1998). Finally, inserting the expression for the rms turbulent velocity [Eq. (13)] in Eq. (12) yields:

$$E_2 = 1.9C \pi R^{7/3} \varepsilon_0^{1/3} \quad (14)$$

Let now ε_λ be a multifractal variable characterized by the scaling moment function $K(q)$ defined above, and by its mean $\langle \varepsilon_\lambda \rangle = \varepsilon_0$. Here, E_2 and E_2' are the estimates of average encounter rates due to turbulence, i.e. $E_2 = E(\varepsilon_0)$ and $E_2' = \langle E(\varepsilon_0) \rangle$ when the turbulent energy dissipation rates are regarded as homogeneous and intermittent (multifractal) variables, respectively. Eq. (14) can thus be rewritten as:

$$E_2' = 1.9C \pi R^{7/3} \varepsilon_0^{1/3} \lambda^{K(1/3)} \quad (15)$$

Now $E_2' = E_2 \lambda^{K(1/3)}$, and as defined above, $\lambda \gg 1$ and $K(1/3) < 0$, $\lambda^{K(1/3)}$ acts as a restraining factor therefore $E_2' < E_2$. Considering values of the inertial subrange scale ratio bounded between 10^2 and 10^3 (e.g. GREGG, 1999), and $K(1/3) = -0.060 \pm 0.003$ (SEURONT and YAMAZAKI, unpublished data), the factor $\lambda^{K(1/3)}$ ranges between 0.50 and 0.76. Taking into account the intermittent structure of turbulent kinetic energy dissipation rate ε_λ instead of an average value ε_0 then decreases the contribution of microscale turbulence to the predator-prey encounter rate of 25% to 50% for ε_0 values ranging from 10^{-10} to $10^{-2} \text{ m}^2 \cdot \text{s}^{-3}$, GREGG, 1999).

4. Discussion and Conclusions

The estimated increase in the rate of nutrient fluxes around non-motile phytoplankton cells (ranging from 6 to 62%) and the decrease in the effects of microscale turbulence on physical coagulation of phytoplankton in an intermittent turbulence condition (ranging from 25% to 48%) could be of prime interest in the general understanding of primary production as well as more general nitrogen and carbon cycling studies.

The strongest rates of nutrient fluxes observed in high turbulent conditions (i.e. up to 62%) could indeed provide a potential phenomenological explanation to the persistence of local high phytoplankton diversity in highly energetic areas referred as the 'paradox of the plankton' (HUTCHINSON, 1961). This hypothesis is supported by Eqs. (6) & (7) which demonstrate that intermittency effects on nutrient fluxes are higher for large phytoplankton cells [21–62%; cf. Eq. (7)] than for smaller ones [6–19%; cf. Eq.(6)], large and small phytoplankton species being respectively characteristic of highly dissipative and still water environments (e.g. MARGALEF, 1997).

On the other hand, the decreased physical coagulation shown here is associated with a decrease in phytoplankton aggregate size (22% to 41%). This change in the growth dynamics of aggregate size due to coagulation directly leads to a weaker enhancement of Stokes' settling velocities and, hence, to decreased vertical fluxes of phytoplankton. As a consequence, the CO_2 storage capacity of the deep ocean

could be weaker than previously thought, and lead to salient effects on carbon cycling estimates between ocean and atmosphere. Consider, for instance, that only 50% of the 22–41% decrease in aggregate size leads to a decrease in the vertical phytoplankton flux, then the deep ocean CO_2 storage capacity could be decreased by 10–20%.

More generally, considerations of the intermittent nature of microscale turbulence could be regarded as a potential new way to improve estimates of key fluxes, such as primary, new and regenerated productions. These estimates are still disputed to within a factor of 10 (see e.g. PLATT *et al.* 1989), mainly because of our limited capacity to harmonize the different measurement procedures and their implied time and space scales (BERGER 1989 : PLATT *et al.* 1989), but also because of the extreme sensitivity of actual numerical modeling, even to minor changes in parameter values (WERNER *et al.* 1993).

In the case of predator-prey interactions, the results presented here indicate a decreased contribution of intermittent microscale turbulence in predator-prey encounter rates ranging between 25% and 50% in low and high hydrodynamic conditions, respectively. Following the likewise relative inadequacy observed between theoretical encounter theory and empirical result of zooplankton grazing in turbulent environment (e.g. DOWER *et al.*, 1997), a new hypothesis for zooplankton trophodynamics [extensively explored elsewhere (SEURONT *et al.*, 2001b)], can be suggested on the basis of different biological and ecological observations. First, zooplankton swimming speeds can overcome local turbulent velocity fluctuations (YAMAZAKI and SQUIRES, 1996), and then become independent of their surrounding physical turbulent environment. Second, microscale phytoplankton distributions are very patchy both in low and high turbulence conditions (JAFFE *et al.*, 1998 : SEURONT *et al.*, 1996a, b, 1999), and result from complex interactions involving turbulence intensity, phytoplankton physiological state and phytoplankton assemblages specific composition (SEURONT, 1999 : SEURONT *et al.*, 2001a). Third, planktonic predators such as copepods present different

behavioral adaptations to food patchiness such as reduced motility in food patches (e. g. BUNDY *et al.*, 1993). Finally, as suggested by their chemosensory abilities (e.g. DOAL *et al.*, 1998; STRICKLER, 1998), planktonic predators can reasonably be regarded as being able to locate food patches and to move from one high density patch to another. Based on these arguments, the phytoplankton distribution experienced by planktonic predators is skewed toward a limited area. The observed increased ingestion under turbulent conditions could then be the results of an active exploitation of food patchiness by predators rather than a direct consequence of an increased predator-prey encounter rates by turbulence. Also, this hypothesis could explain the discrepancy observed by SAIZ (1994) between empirical encounter rates and the theoretical values expected using ROTHSCHILD and OSBORN theory.

Taking both the coherent nature of turbulence at the scale of planktonic organisms, and the individual behavior of plankton organisms (KEIYU *et al.*, 1994), this article provides a general theoretical approach for testing the potential effects of intermittent distributions on ocean fluxes, and could also be advantageously coupled with recent modeling approaches for individual adaptations to heterogeneously distributed resources (RAMAT *et al.*, 1998; SEURONT *et al.*, 2001b).

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Size-fractionated chlorophyll *a* and primary productivity in the offshore Oyashio waters in July 1992

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Abstract : Size-fractionated (<2, 2-10 and 10-200 μ m) chlorophyll *a* (Chl *a*) concentration and primary productivity were determined at the 100 (surface), 30, 10 and 1% light depths at four stations in the offshore Oyashio waters in July 1992. The share of the <2 or 2-10 μ m fraction was the highest in the total Chl *a* concentration and primary productivity at all the stations and light depths, except at the 10% light depth at one station. Each of the <2 and 2-10 μ m fractions accounted for 40-50% of the total on average, and the 10-200 μ m fraction accounted for 10-15% of the total on average. The 10-200 μ m fraction accounted for 45% of the total Chl *a* concentration and primary productivity at the 10% light depth at the one station. Such exception can be attributed to the availability of higher concentration of nitrogenous nutrients (mostly nitrate) and absence of light limited condition for phytoplankton of the 10-200 μ m fraction. We suggest that, in the offshore Oyashio waters in summer, small-sized phytoplankton generally contribute to phytoplankton biomass and productivity, and large-sized phytoplankton contribute likewise when high concentration of nitrate is available at depths with enough light intensity for their growth.

Key words : chlorophyll *a*, primary productivity, size fractionation, offshore Oyashio waters, nitrate availability, light intensity

1. Introduction

Many shipboard studies have been carried out to determine the total and size-fractionated chlorophyll *a* (Chl *a*) concentration and primary productivity in the eastern region of the subarctic North Pacific, the Alaskan Gyre (e.g., BOOTH *et al.*, 1993; WELSCHMEYER *et al.*, 1993; BOYD and HARRISON, 1999). The results show that small-sized (<5 μ m) phytoplankton generally contribute to total Chl *a* and primary productivity. In the Oyashio waters located in the western region of the subarctic North Pacific, total Chl *a* and primary productivity have been measured in many shipboard observations (e.g., SHIOMOTO *et al.*, 1994; KASAI *et al.*, 1998; SHIOMOTO, 2000). However, there are a few measurements of size-fractionated Chl *a* concentration (MAITA and ODATE, 1988; ODATE and

MAITA, 1988/89; TAGUCHI *et al.*, 1992; SHIOMOTO *et al.*, 1994; ODATE, 1996). Size-fractionated primary productivity was reported only in the coastal region in Funka Bay located in the southwestern Hokkaido (MAITA and ODATE, 1988). Results from these studies in the Oyashio waters showed that small-sized phytoplankton (<2 μ m) contributed significantly to phytoplankton biomass and productivity. The dominant species and size of the phytoplankton have much influence on relationship between different components of marine ecosystem (e.g., PARSONS *et al.*, 1984b; STOCKNER and ANTIA, 1986). Hence, it is necessary to investigate further the relative contribution of phytoplankton of different size fractions, for the progress of ecosystem studies in the Oyashio waters.

Under the present investigation, we measured the size-fractionated Chl *a* and primary productivity in the offshore Oyashio water (salinity <33.4; OHTANI, 1971; KAWAI, 1972) in

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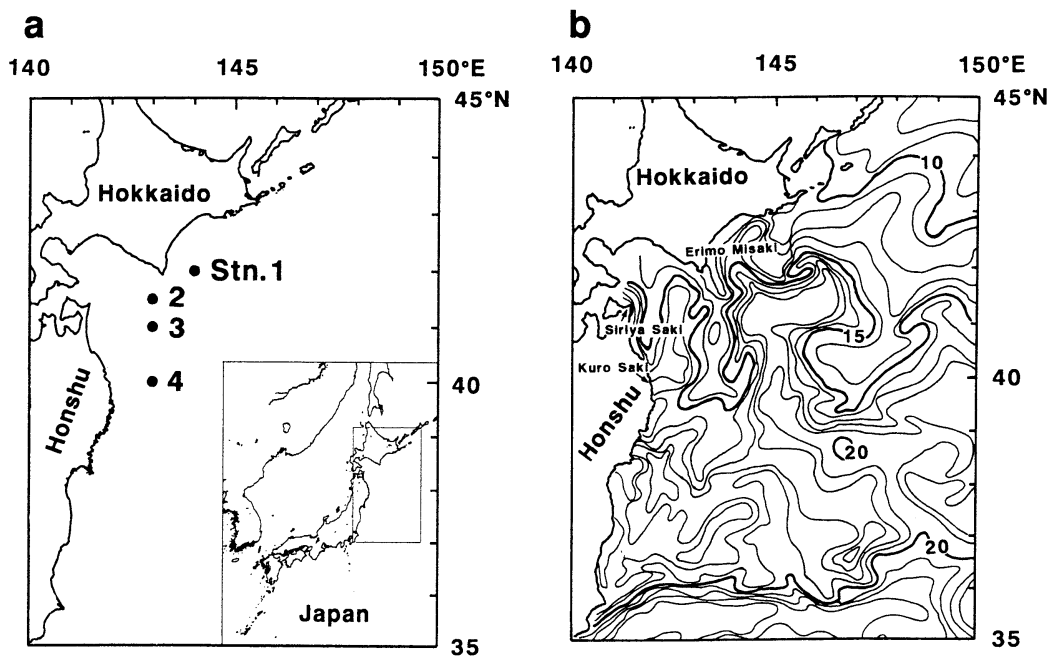


Fig. 1. a: Location of sampling stations in the offshore Oyashio waters, July 1992; b: horizontal distribution of the surface temperature ($^{\circ}\text{C}$) for 6–10 July 1992 (Japan Fisheries Information Service Center, 1992).

summer. We suggest that small-sized phytoplankton generally contribute to phytoplankton biomass and productivity, and large sized phytoplankton contribute likewise when high concentration of nitrate is available at depths with enough light intensity for their growth.

2. Materials and Methods

This study was conducted during a cruise of the R/V *Shunyo Maru* of the National Research Institute of Far Seas Fisheries in the offshore Oyashio waters in 7–12 July 1992 (Fig. 1a). Seawater samples were collected between 0730 and 0800 hours from four depths corresponding to 100, 30, 10 and 1% light depths using an acid cleaned 30-l Go-Flo sampler hung on a stainless steel wire. The light depths were determined 30 minutes before sample collection with a cosine response quantum sensor (LI-COR 192SA). The water samples were then sieved through a 200 μm mesh screen to remove large zooplankton.

The total and size-fractionated Chl *a* concen-

trations were measured by fluorometry (PARSONS *et al.*, 1984a). Total Chl *a* was determined in samples (0.5–1) filtered through 47 mm Whatman GF/F filters. Size-fractionated Chl *a* was measured in samples (0.5–1) obtained as follows: seawater samples were filtered through 2 and 10 μm pore size Nuclepore filters and the filtrates were then refiltered onto 47 mm Whatman GF/F filters (<2 and <10 μm fractions). The filters were then stored frozen at -20°C until analysis ashore. Pigments were extracted in 90% acetone and the fluorescence was measured with a Hitachi F-2000 fluorophotometer. Calibration of the fluorophotometer was performed with commercially prepared Chl *a* from Wako Pure Chemical Industries, Ltd. (Tokyo). Chl *a* concentrations for the 2–10 and 10–200 μm fractions were obtained from the differences between the <10 and <2 μm fractions and between the total and <10 μm fraction, respectively.

Total and size-fractionated primary productivity was determined by the ^{13}C method

(HAMA *et al.*, 1983). The primary productivity experiments were started within 1 hour after sampling. The seawater samples (2-l) were dispensed into two acid-cleaned 2-l polycarbonate bottles and enriched by the addition (1-ml) of $\text{NaH}^{13}\text{CO}_3$ (99 atom% ^{13}C ; Shoko Co., Ltd., Tokyo) to about 10% of the total inorganic carbon in ambient water. Incubations were conducted by the in situ method for 3–3.5 hours. The fractionation of the samples into size classes was carried out after incubation. Immediately after the incubation, an aliquot of 0.5-l of the seawater samples was filtered directly through precombusted (450°C for 4 hours) 47mm Whatman GF/F filters (total). Aliquots of 0.5-l of the remaining seawater samples were filtered through Nuclepore filters with pore sizes of 2 and 10 μm . The filtrates were refiltered onto 47 mm Whatman GF/F filters (<2 and <10 μm fractions) and the particulate matter on the Whatman GF/F filters was rinsed with prefiltered seawater. The filters were then stored frozen at -20°C until analysis ashore. They were treated with HCl fumes for 4 hours to remove inorganic carbon and completely dried in a vacuum desiccator. The isotopic ratios of ^{13}C to ^{12}C and particulate organic carbon were determined with a mass spectrometer (ANCA SL, PDZ Europa Ltd.). Total inorganic carbon in the water was measured with an infrared analyzer (Shimadzu TOC 5000). Primary productivity was calculated according to the equation described by HAMA *et al.* (1983). Size-fractionated primary productivity was estimated in the same manner as the Chl *a* concentration. Primary productivity obtained in the two bottles was averaged.

Vertical profiles of temperature and salinity were measured using a Neil Brown CTD Mark II. Seawater samples for determining nutrient concentrations were stored frozen until analysis ashore. The concentrations were determined using a Bran and Luebbe Auto Analyser Traccs 800.

3. Results

3.1 General oceanographic conditions

Based on horizontal distribution of the surface temperature in early July 1992 (Fig. 1b), the coastal and offshore regions of the eastern

Hokkaido through Erimo Misaki were occupied by the first Oyashio Intrusion, which was identified as 14°C at the surface, and the southern edge of the water was observed off Sanriku. The extension of the Tsugaru Warm Current, which was identified as $16\text{--}17^\circ\text{C}$ at the surface, was observed off Siritaya Saki through Kuro Saki.

Vertical profiles of temperature, salinity and density (σ_t) in the upper 100 m are shown in Fig. 2. The temperature was $15\text{--}17^\circ\text{C}$ at the surface and decreased with depth at every station. Salinity in the upper 50 m at Stns. 1 and 4, in the upper 30 m at Stn. 2, and in the upper 20 m at Stn. 3 was less than 33.4. The depths of 50 m at Stns. 1 and 4 were located below the depths of the euphotic zone (1% light depth). The depths of 30 m at Stn. 2 and 20 m at Stn. 3 were located below the depths of the 10% light depth. Accordingly, the water mass within the euphotic zone at Stns. 1 and 4 and in the upper 10% light depth at Stns. 2 and 3, belonged to the Oyashio water. All stations were noticed to be located in the first Oyashio Intrusion. Moreover, salinity exceeding 33.5 was observed deeper than 30 m at Stn. 2 and at 20–30 m at Stn. 3. Judging from the surface temperature distribution (Fig. 1b) and salinity, the bottom of the euphotic zone at Stns. 2 and 3 was possibly affected by the Tsugaru Warm Current (salinity >33.7 ; OHTANI, 1971; HANAWA and MITSUDERA, 1987). The σ_t was almost constant in the top 10 m and increased with depth below 10 m at Stns. 1 and 4, whereas the σ_t increased with depth at Stns. 2 and 3. The zone where the σ_t changed markedly with depth, that is, the pycnocline, was between 10 and 30 m at Stns. 1 and 4, and between 0 and 20 m at Stns. 2 and 3.

3.2 Nutrients

The vertical profiles of nutrient concentrations in the upper 1% light depth are shown in Fig. 3. Nitrite + nitrate ($\text{NO}_2 + \text{NO}_3$; mostly nitrate) was nearly exhausted in the upper 30 or 10% light depth at Stns. 2, 3 and 4. Nitrite + nitrate concentrations were very low in the upper 30% light depth at Stn. 1, but it was not exhausted. The concentrations increased rapidly from below the 30% light depth at Stns. 1 and 4, and from below the 10% light depth at

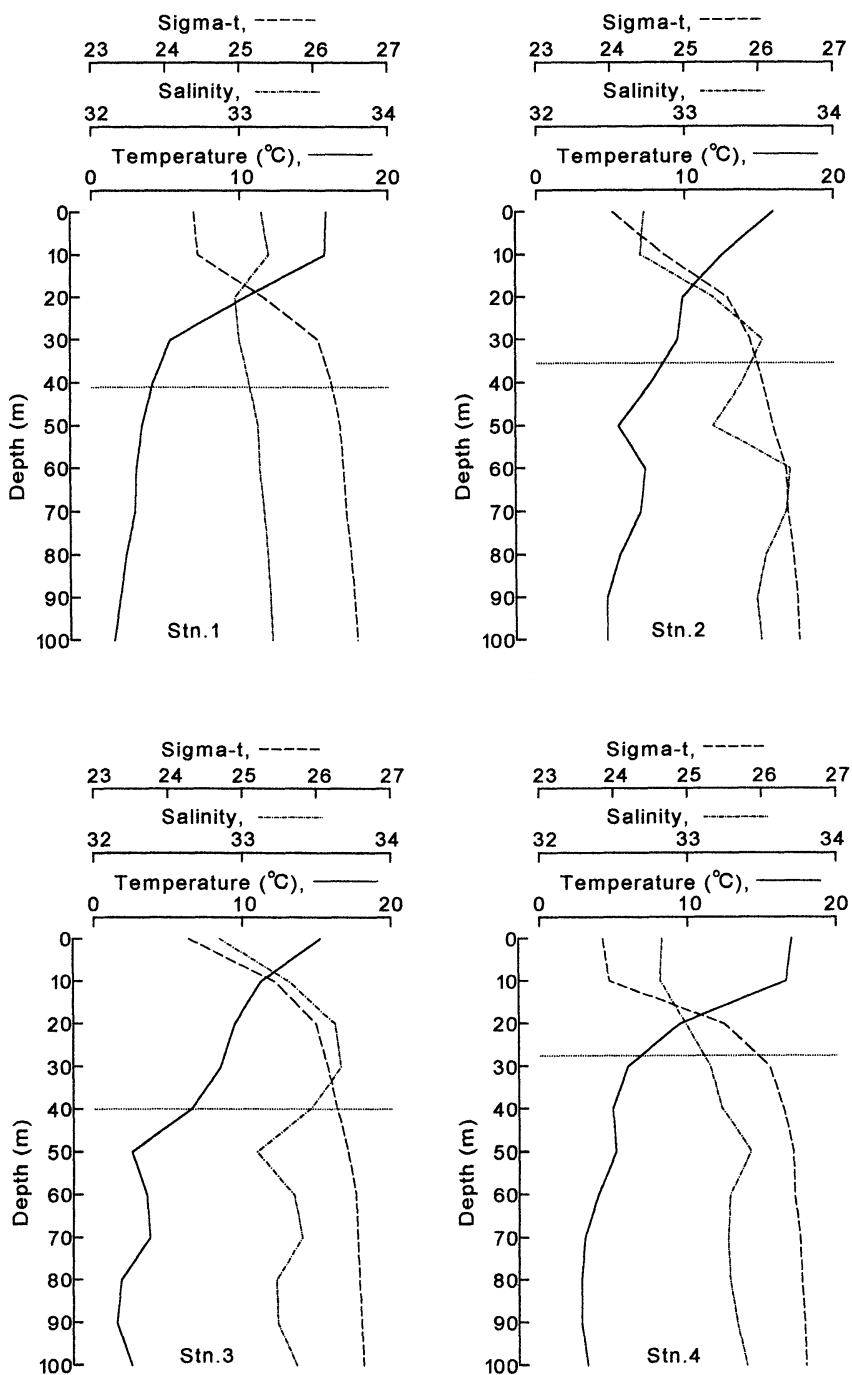


Fig. 2. Vertical profiles of temperature, salinity and sigma-t in the upper 100m. Horizontal dotted lines indicate the bottom of the euphotic zone (1% light depth).

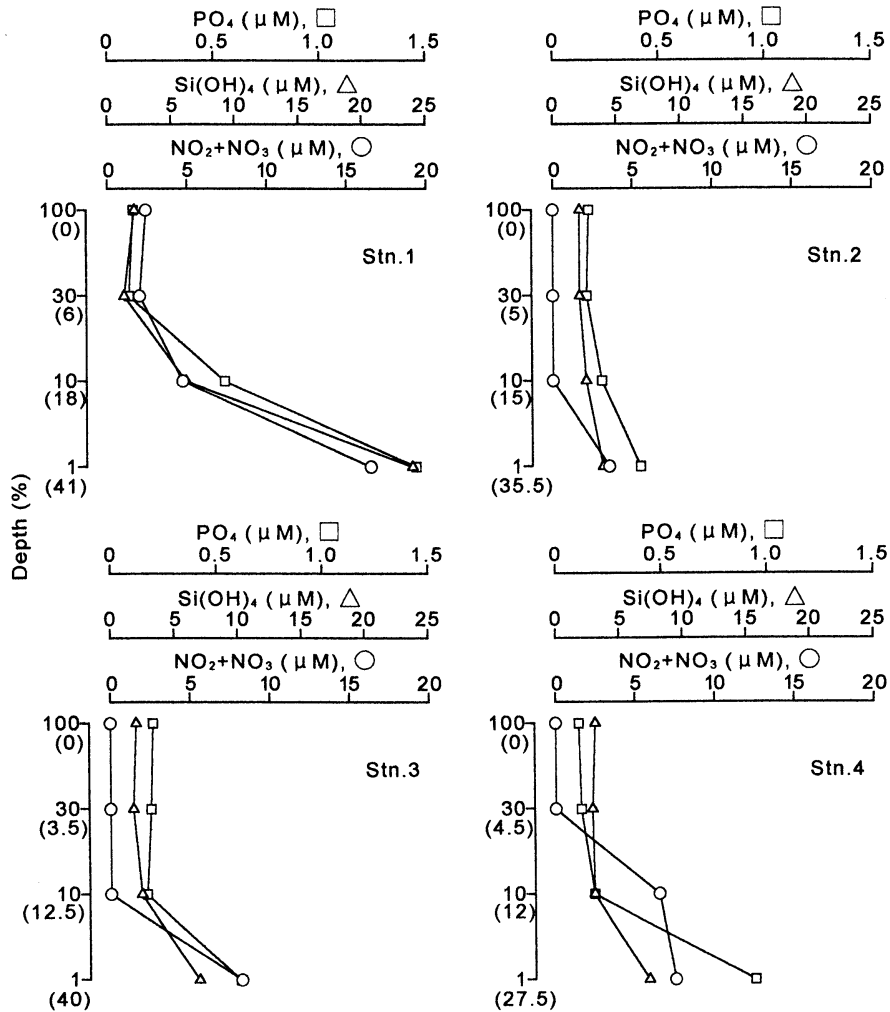


Fig. 3. Vertical profiles of nitrite + nitrate ($\text{NO}_2 + \text{NO}_3$), silicate [$\text{Si}(\text{OH})_4$] and phosphate (PO_4) concentrations in the upper 1% light depth. Depths in meters are given in the parentheses.

Stns. 2 and 3. The concentrations below the 1% light depth (30–40 m) were generally between 10 and 20 μM in the upper 100 m at Stns. 1, 3 and 4 and between 5 and 10 μM at Stn. 2 (not shown). Almost the same trends were observed in vertical profiles of silicate [$\text{Si}(\text{OH})_4$] and phosphate (PO_4) concentrations, though neither nutrient was exhausted even in the upper 10% light depth.

3.3 Chlorophyll *a*

Total Chl *a* concentrations were between 0.2

and 0.4 $\mu\text{g l}^{-1}$ at the 100 and 30% light depths, and between 0.5 and 1.5 $\mu\text{g l}^{-1}$ at the 10 and 1% light depths, except the 1% light depth at Stn. 3 (Fig. 4a). Total Chl *a* concentrations tended to be higher at the 10 and 1% light depths than at the 100 and 30% light depths. Similar trend was found in the Chl *a* concentrations of each size fraction.

The relative size composition of Chl *a* concentration is shown in Fig. 4b. The <2 or 2–10 μm fraction was the most abundant except at the 10% light depth at Stn. 4, accounting for

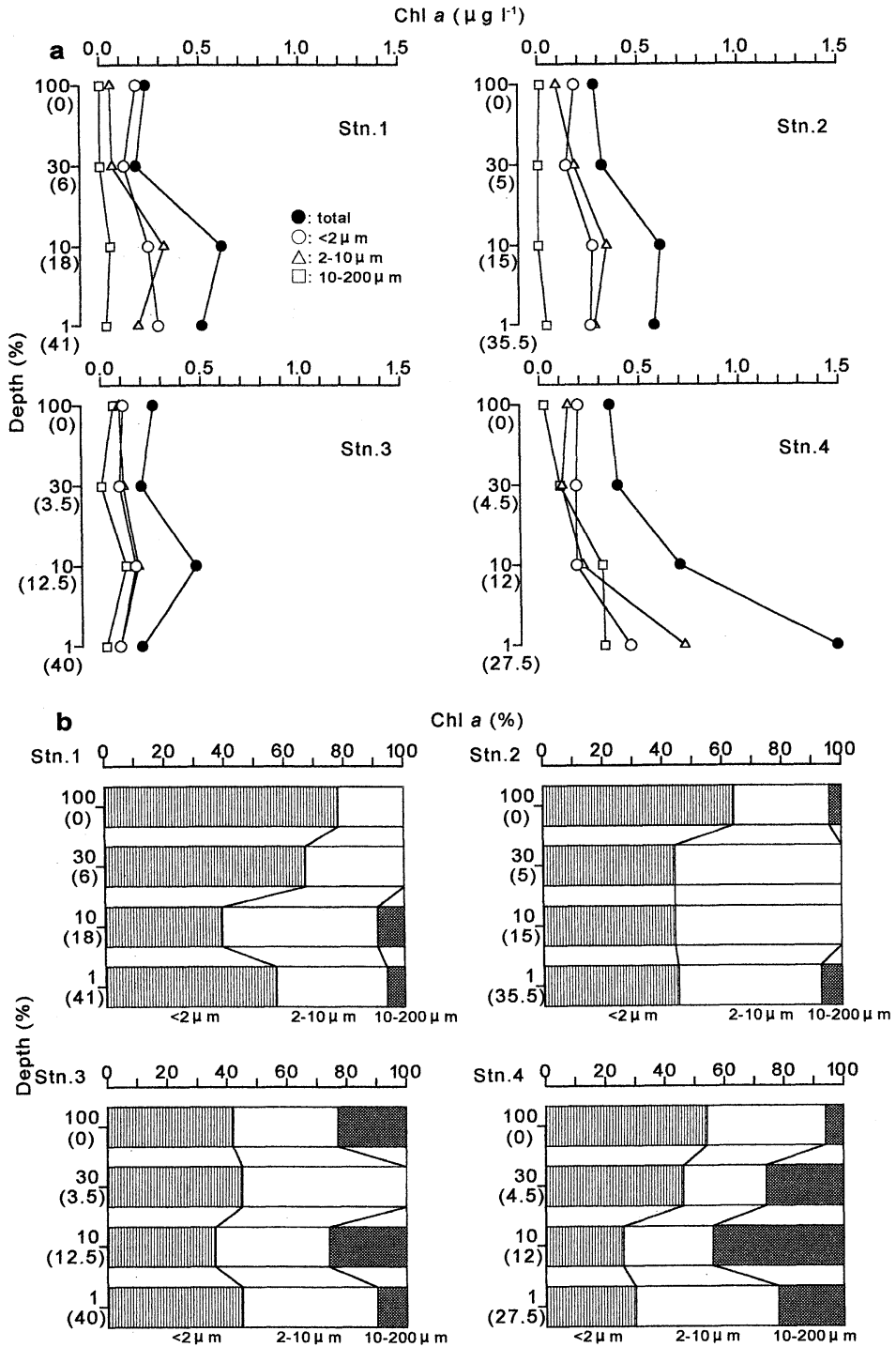


Fig. 4. a: Vertical profiles of total and size-fractionated chlorophyll *a* (Chl *a*) concentrations in the upper 1% light depth; b: relative size composition of chlorophyll *a* concentration in the upper 1% light depth. Depths in meters are given in the parentheses.

38–78% of the total. The sum of the two fractions accounted for 74–100% of the total, except at the 10% light depth at Stn. 4. The 10–200 μm fraction was the most abundant at the 10% light depth at Stn. 4, accounting for 44% of the total. Mean \pm SD of Chl *a* concentration of the <2 , 2–10 and 10–200 μm fractions were $48 \pm 14\%$ ($n=16$), $41 \pm 11\%$ ($n=16$) and $11 \pm 13\%$ ($n=16$), respectively, using all of the data.

3.4 Primary productivity

Total primary productivity was between 0.4 and $4.0 \mu\text{g C l}^{-1} \text{h}^{-1}$ (Fig. 5a). Maximum productivity was observed at the 10% light depth at Stns. 1 and 4, and at the 30% light depth at Stn. 3. In contrast, productivity was nearly constant in the upper 10% light depth at Stn. 2. Productivity rapidly decreased at the 1% light depth at Stns. 1 and 2. Vertical profiles similar to total primary productivity were found in the primary productivity of the 10–200 μm fraction at Stns. 1, 2 and 4. Distinct increases in primary productivity were found in this fraction at the 10% light depth at Stns. 1 and 4. Primary productivity of the 10–200 μm fraction was almost equal to or higher than those of the other fractions at the 10% light depth at the two stations.

The relative size composition of primary productivity is shown in Fig. 5b. The <2 or 2–10 μm fraction was the most abundant except at the 10% light depth at Stn. 4, accounting for 37–85% of the total. The sum of the two fractions accounted for 68–100% of the total, except at the 10% light depth at Stn. 4. The 10–200 μm fraction was the most abundant at the 10% light depth at Stn. 4, accounting for 45% of the total. The same result as Chl *a* was found in primary productivity. Mean \pm SD of primary productivity of the <2 , 2–10 and 10–200 μm fractions were $38 \pm 16\%$ ($n=15$), $47 \pm 17\%$ ($n=15$) and $15 \pm 13\%$ ($n=15$), respectively, using all of the data.

4. Discussion

Our results show that the share of the <2 or 2–10 μm fraction was highest in the total Chl *a* concentration and primary productivity at all the stations and light depths, except at the 10% light depth at Stn. 4. Our results furthermore show that the sum of the two fractions

accounted for more than about 70% of the total Chl *a* concentration and primary productivity. Thus, we noticed that small-sized phytoplankton generally contribute significantly to phytoplankton biomass and productivity. This is consistent with the limited information available regarding the size composition of the phytoplankton biomass and productivity in the Oyashio waters in summer (MAITA and ODATE, 1988; TAGUCHI *et al.*, 1992; ODATE, 1996).

At the 10% light depth at Stn. 4, the large sized phytoplankton contributed more to the phytoplankton biomass and productivity compared to smaller fractions. ODATE and MAITA (1988/89) showed that the variation in Chl *a* concentration of the $>10 \mu\text{m}$ fraction depended on that in cell density of the $>10 \mu\text{m}$ sized diatoms in the northwestern Pacific. According to SHIOMOTO *et al.* (1994, 1996), the cell density of diatoms was more abundant in the case which the $>10 \mu\text{m}$ fraction dominated the Chl *a* concentration, compared with the case which the $<10 \mu\text{m}$ fraction dominated the Chl *a* concentration in the northwestern Pacific. It is thus highly possible that the high contribution of large-sized phytoplankton to the phytoplankton biomass and productivity at the 10% light depth at Stn. 4 reflected prevalence of large-sized diatoms. What are the factors then that lead to the high contribution of the large-sized phytoplankton (diatoms) to the biomass and productivity?

Large-sized phytoplankton prefer higher nutrient concentrations than small-sized phytoplankton (PARSONS and TAKAHASHI, 1973; MALONE, 1980). The concentrations of nitrogenous nutrients (mostly nitrate) were markedly low in the euphotic zone (in the upper 1% light depth) at all stations, and they were nearly exhausted in the upper 30 or 10% light depth (Fig. 3). One possibility, therefore, is that availability of higher concentration of nitrate played an important role leading to the high contribution of large-sized phytoplankton to phytoplankton biomass and productivity at the 10% light depth at Stn. 4. Such assumption can further be supported by the following observation.

Chl *a*-specific primary productivity is an index of the phytoplankton growth rate (LALLI

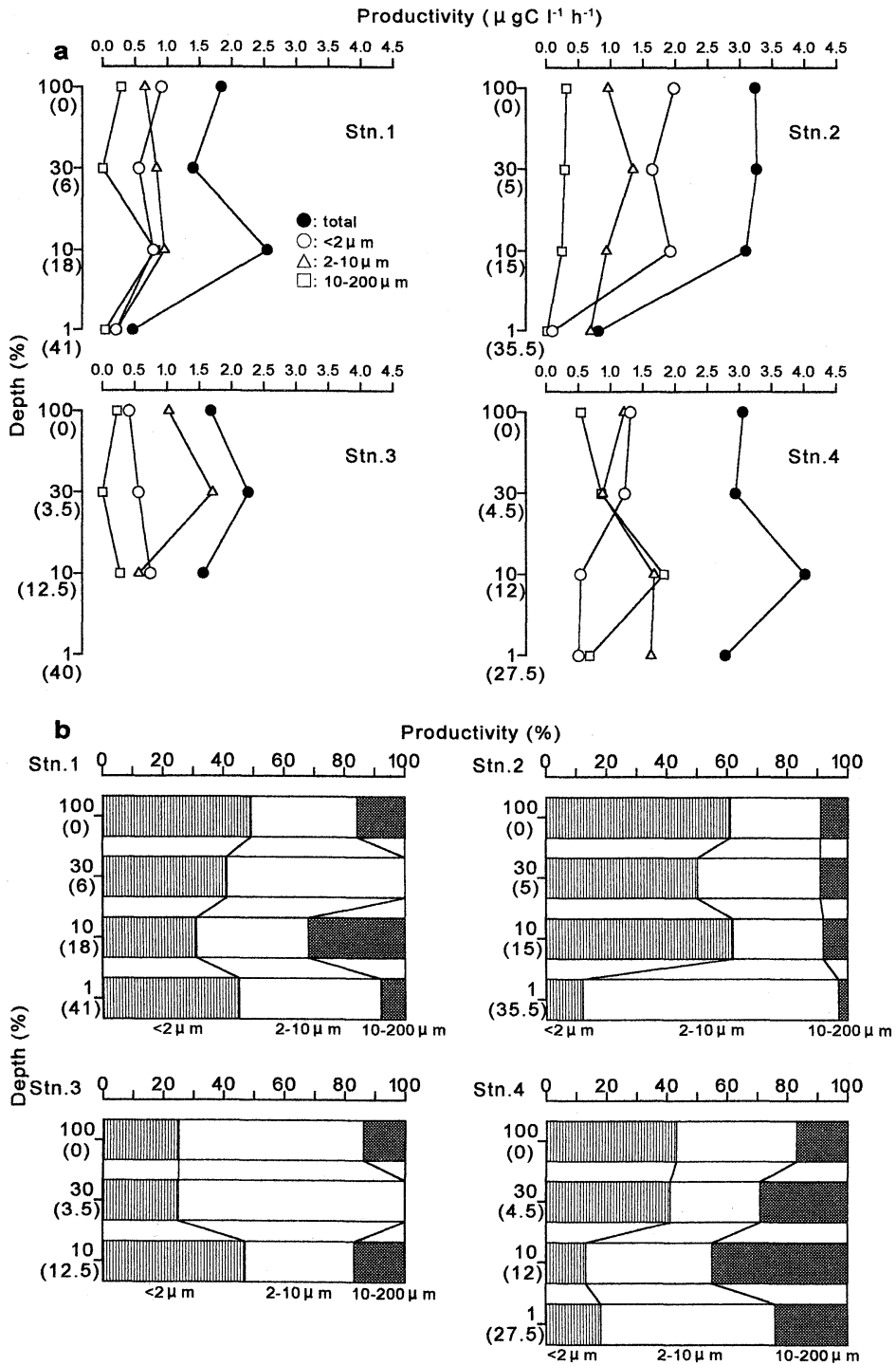


Fig. 5. a: Vertical profiles of total and size-fractionated primary productivity in the upper 1% light depth; b: relative size composition of primary productivity in the upper 1% light depth. Depths in meters are given in the parentheses.

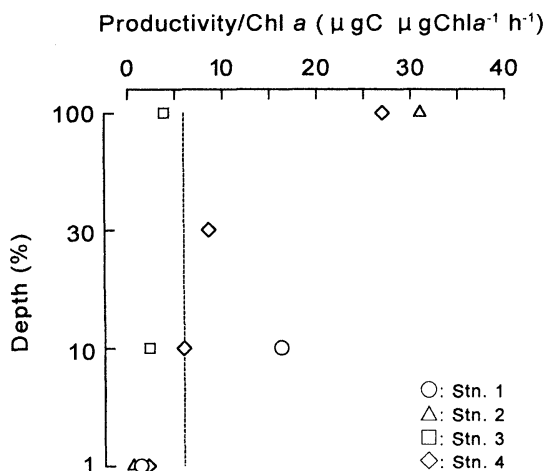


Fig. 6. Chl *a*-specific primary productivity (Productivity/Chl *a*) of the 10–200 μm fraction at the 100, 30, 10 and 1% light depths at Stns. 1, 2, 3 and 4. The Chl *a*-specific primary productivity could not be calculated at the 100 and 30% light depths of Stn. 1, at the 30 and 10% light depths of Stn. 2 and at the 30% light depth of Stn. 3, because Chl *a* concentrations were almost equal to 0 $\mu\text{g l}^{-1}$. The vertical broken line indicates Productivity/Chl *a* at the 10% light depth of Stn. 4.

and PARSONS, 1993). The Chl *a*-specific primary productivity of the 10–200 μm fraction was markedly lower at the 1% light depth at all stations (Fig. 6), indicating that large-sized phytoplankton growth was limited by light intensity at the 1% light depth but not in the upper 10% light depth. It is thus unlikely that the large-sized phytoplankton contributed to the phytoplankton biomass and productivity at the 1% light depth even if plentiful nitrate was supplied to the light depth.

Ambient nutrient concentration is dependent on the balance between supply and consumption. Total primary productivity at the 10% light depth at Stn. 4 ($4.0 \mu\text{g C l}^{-1} \text{ h}^{-1}$) was higher than the remaining eleven discrete values ($1.4\text{--}3.3 \mu\text{g C l}^{-1} \text{ h}^{-1}$) in the upper 10% light depth at all four stations (Fig. 5). This implies that relatively much nitrate was consumed at the 10% light depth at Stn. 4 compared with the rest. Likewise, ambient nitrate concentration at the 10% light depth at Stn. 4 ($6.5 \mu\text{M}$) was higher than the remaining eleven values (less than $4.7 \mu\text{M}$) in the upper 10% light depth

at all stations (Fig. 3). It is thus highly possible that higher concentration of nitrate was available at the 10% light depth at Stn. 4 compared with the rest.

The Chl *a*-specific primary productivity of the 10–200 μm fraction was $5.9 \mu\text{gC } \mu\text{gChl } a^{-1} \text{ h}^{-1}$ at the 10% light depth at Stn. 4 where large sized phytoplankton mostly contributed to the total phytoplankton biomass and productivity. Values exceeding $5.9 \mu\text{gC } \mu\text{gChl } a^{-1} \text{ h}^{-1}$ were frequently observed in the upper 10% light depth (Fig. 6), indicating that large-sized phytoplankton have the capacity to contribute to the phytoplankton biomass and productivity in the upper 10% light depth. We therefore suggest that, in the offshore Oyashio waters in summer, small-sized phytoplankton generally contribute to the phytoplankton biomass and productivity, and large-sized phytoplankton contribute likewise when high concentration of nitrate is available at depths with enough light intensity for their growth.

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東京湾における栄養塩の動向 (1989-1998年)

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Recent trends of nutrients in Tokyo Bay (1989-1998)

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Abstract : Nutrient concentrations were investigated from 1994 to 1998 in Tokyo Bay and trends in recent ten years of nutrient concentrations were discussed. DIN and $PO_4\text{-P}$ were high in winter and low in summer, while $Si(OH)_4\text{-Si}$ was low in winter and high in summer. DIN/DIP (DIP= $PO_4\text{-P}$) ratio was much higher than 16 in winter and decreased to about 16 in summer, because desorption of phosphorus from the sediment was active in summer. DSi/DIN (DSi= $Si(OH)_4\text{-Si}$) ratio was lower than 1, which is an average Si/N ratio of diatoms, in winter and higher in summer. Thus, the reason why diatoms are recessive in summer and dominant in winter is due to other factor than $Si(OH)_4\text{-Si}$ concentration. For ten years between 1989 and 1998, DIN and $Si(OH)_4\text{-Si}$ concentrations were a little decreased. But DIN concentration is still high and may not control phytoplankton production. Decrease of DIN concentration was not explained from the increase of Chl *a* concentration caused by the increase of solar radiation.

Key words : Tokyo Bay, nutrients, Redfield ratio, seasonal change

1. はじめに

東京湾の富栄養化は1960年代から急激に進行し、それにもとない湾内のDINや $PO_4\text{-P}$ の濃度が急激に増加した(宇野木・岸野, 1977)。東京湾における1990年までの栄養塩濃度の変動については高田(1993)や野村(1995)によりまとめられている。それらによると、 $NH_4\text{-N}$ は1970年頃をピークにやや減少したが、 $NO_3\text{-N}$ および $NO_2\text{-N}$ は増加し続けており、結果としてDINは一貫して増加し続けた。 $PO_4\text{-P}$ 濃度については1970年頃にピークに達し、それ以降は合成洗剤の無リン化などによりやや減少し、1980年頃以降は平均 $1\mu\text{M}$ 程度で推移した。 $Si(OH)_4\text{-Si}$ は1970年頃までは濃度が低下する傾向にあり、1990年頃は1970年頃とはほぼ同じ濃度レベルであると述べられている。また、山口・柴田(1979)、山口(1999)は、1970年頃以降東京湾では栄養塩が植物プランクトンの増殖を制限することはほとんどなくなったと述べている。

近年の東京湾の栄養塩濃度に関しては、KAWABE and

KAWABE (1997b)が東京都、神奈川県、千葉県の実験データを整理し、1980-1989年の間のDINの変動傾向について調べたものがあり、また魚ほか(1995)は1989年から1993年にかけての5年間の観測結果から、季節変動についてまとめている。本研究では1994年から1998年の毎月1回の湾内定点の観測結果から、栄養塩濃度の最近の状況について調べ、さらに1989-1998年にかけての10年間の栄養塩濃度の経年変動について論じた。

2. 材料と方法

観測は1989-1998年にかけて毎月1回(ただし1992年8月は2回)、東京水産大学研究練習船青鷹丸または実習艇ひよどりにより、多摩川河口沖に位置するSta. F3(水深約23m)と木更津沖のSta. F6(水深約26m)の2点(Fig. 1)で行った。各観測点でCTDを用いて水温・塩分について観測を行った。同時に表面採水バケツ、ロゼット採水器またはバンドン採水器を用いて、Sta. F3では0・5・10・15・20mの5層、Sta. F6では0・5・10・15・20・25mの6層で採水を行った。

得られた海水は栄養塩およびChl *a*の分析に用いた。栄養塩は海水50mlをWhatman GF/Fフィルターを用いて濾過し、濾液を凍結保存後、 $NO_3\text{-N}$ 、 $NO_2\text{-N}$ 、 $NH_4\text{-N}$ 、 $PO_4\text{-P}$ および $Si(OH)_4\text{-Si}$ について分析した。 $NO_2\text{-N}$ はTechniconのマニュアル(1978)に従い、 $NO_3\text{-$

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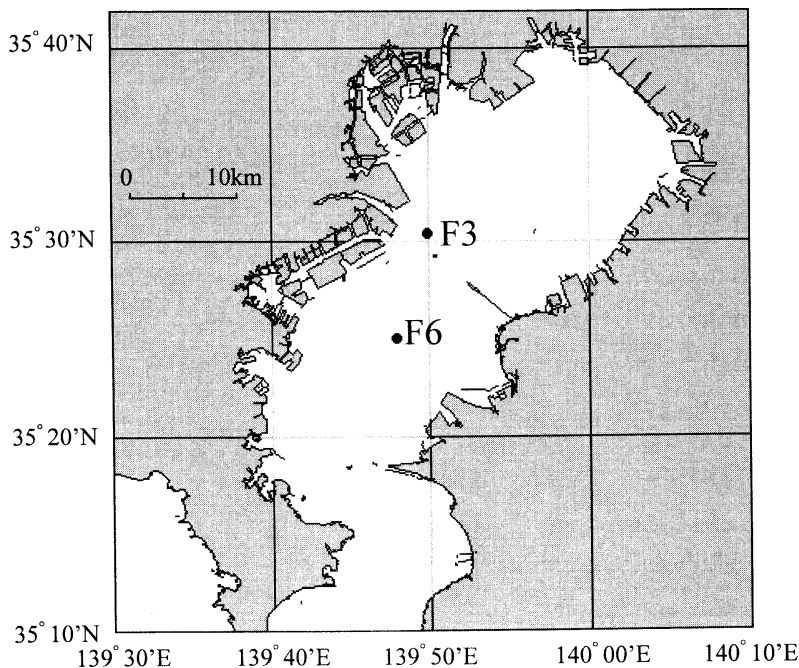


Fig. 1. Observation stations F3 and F6 in Tokyo Bay.

N は Cu-Cd カラムで還元し $\text{NO}_2\text{-N}$ と同じ方法で、また $\text{NH}_4\text{-N}$ は Yu *et al.* (1994) のサリチル酸ナトリウム、ジクロロイソシアニル、ニトロプルシドを用いる方法で、それぞれオートアナライザーを用いて分析した。リン酸は MURPHY and RIELY (1962) の方法で、珪酸は KOROLEFF (1983) のモリブデン青法でそれぞれ手分析で測定を行った。

Chl *a* は栄養塩の濾過に用いたフィルターを SUZUKI and ISHIMARU (1990) に従い、N, N-Dimethylformamid により抽出し、Turner Design 10R 型蛍光光度計を用いて蛍光法 (STRICKLAND and PARSONS, 1972) により分析した。1989-1993 年のデータは魚 (1994) より引用した。

3. 結果と考察

3-1 海洋構造および Chl *a* 濃度の季節変動

栄養塩の濃度は、生物による取り込み、排出や物理的な移流拡散、水塊の混合などに大きく支配されている (例えば、才野, 1985)。そこでまず、海洋構造および Chl *a* 濃度の季節変動について述べる。

Fig. 2 に Sta. F3, Fig. 3 に Sta. F6 における 1994 年 1 月から 1998 年 12 月にかけての水温、塩分、 σ_t および Chl *a* 濃度の季節変動をそれぞれ示す。

表層の水温は Sta. F3 では 8.5-28.7°C, Sta. F6 では

8.3-27.8°C の間で変動し、両測点とも毎年 8 月に最も高く 1, 2 月に最も低くなった。底層の水温は Sta. F3 では 9.6-22.1°C, Sta. F6 では 10.2-22.7°C の間で変動し、表層より 1 ヶ月程度遅れて 9, 10 月に最も高く、表層とほぼ等しく 1, 2 月に最も低くなった。鉛直的に見ると春・夏季は底層より表層の水温が高く、海面冷却が進む 10, 11 月から 3 月頃にかけては逆に表層より底層の水温がやや高かった。1994-1996 年は両測点ともに 2 月に 0-20m 層までの水温が 10°C 以下にまで低下しているが、1997 年以降は低下しなかった。また、いずれの年も混合は海底には及ばなかった。

表層の塩分は Sta. F3 では 15.1-32.4 psu, Sta. F6 では 23.8-32.9 psu の間で変動し、6, 7 月の梅雨および 9, 10 月の秋雨の時期に最も低く、冬季の 1 月頃に最も高かった。表層の塩分の最低値は両測点とも 1998 年 10 月に見られ、 σ_t も低塩分を反映し極端に低くなっている。これは、観測前日 (10 月 1 日) の大雨により淡水流入量が増大したためと考えられる。底層では Sta. F3 では 32.0-34.3 psu, Sta. F6 では 32.5-34.1 psu の間であり、表層に比べて変動幅は小さかった。表層とは逆に、底層の塩分は 1 月頃に最も低かった。これは、宇野木・岸野 (1977) が指摘しているように、冬季は水柱が混合しやすく、底層水が表層の低塩分水の影響を受けるためと考えられる。底層の塩分が 34 以上の高塩分水が Sta.

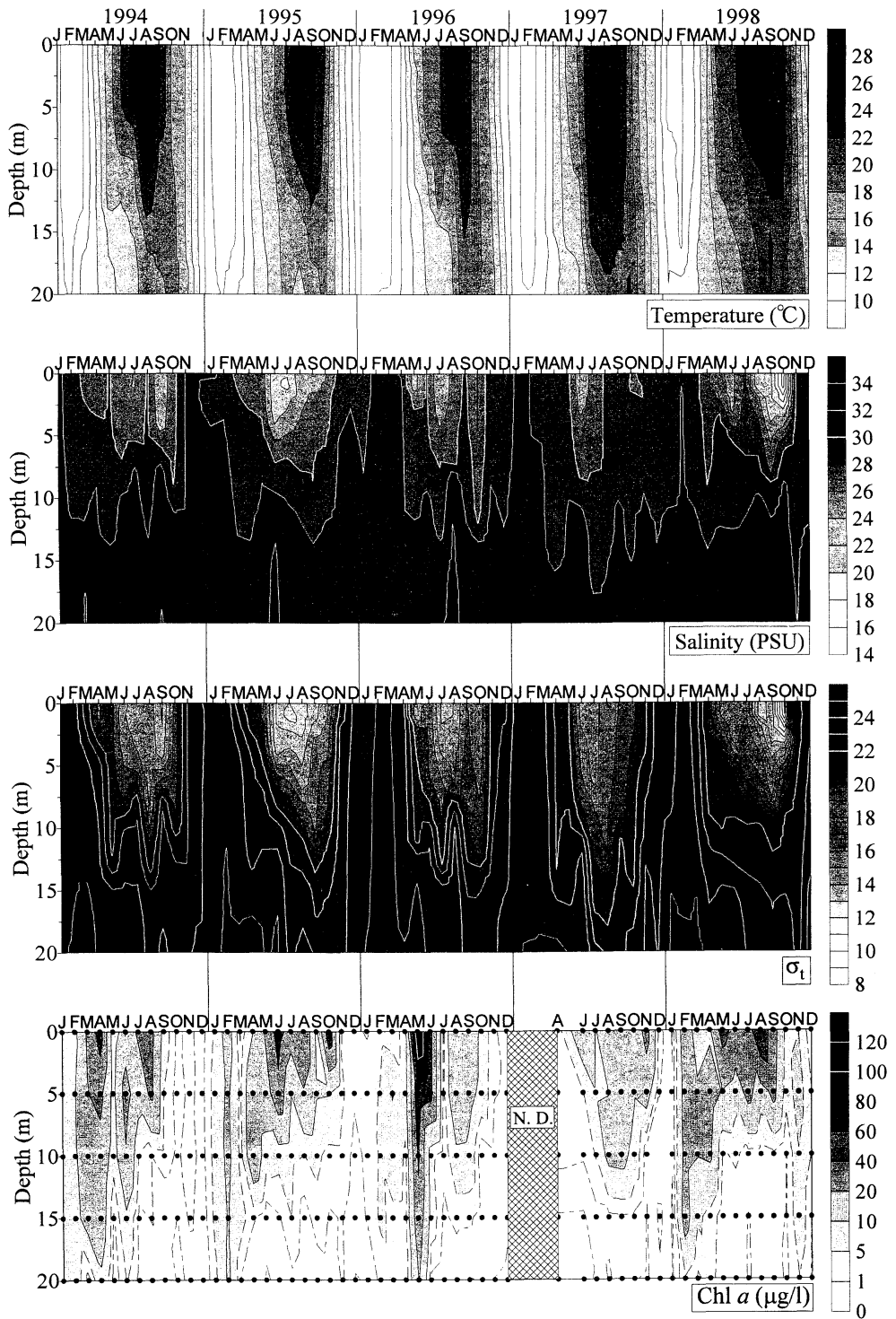


Fig. 2. Seasonal variation in vertical distribution of temperature, salinity, sigma-t and Chl *a* at station F3 in Tokyo Bay from January 1994 to December 1998. N. D. = No data.

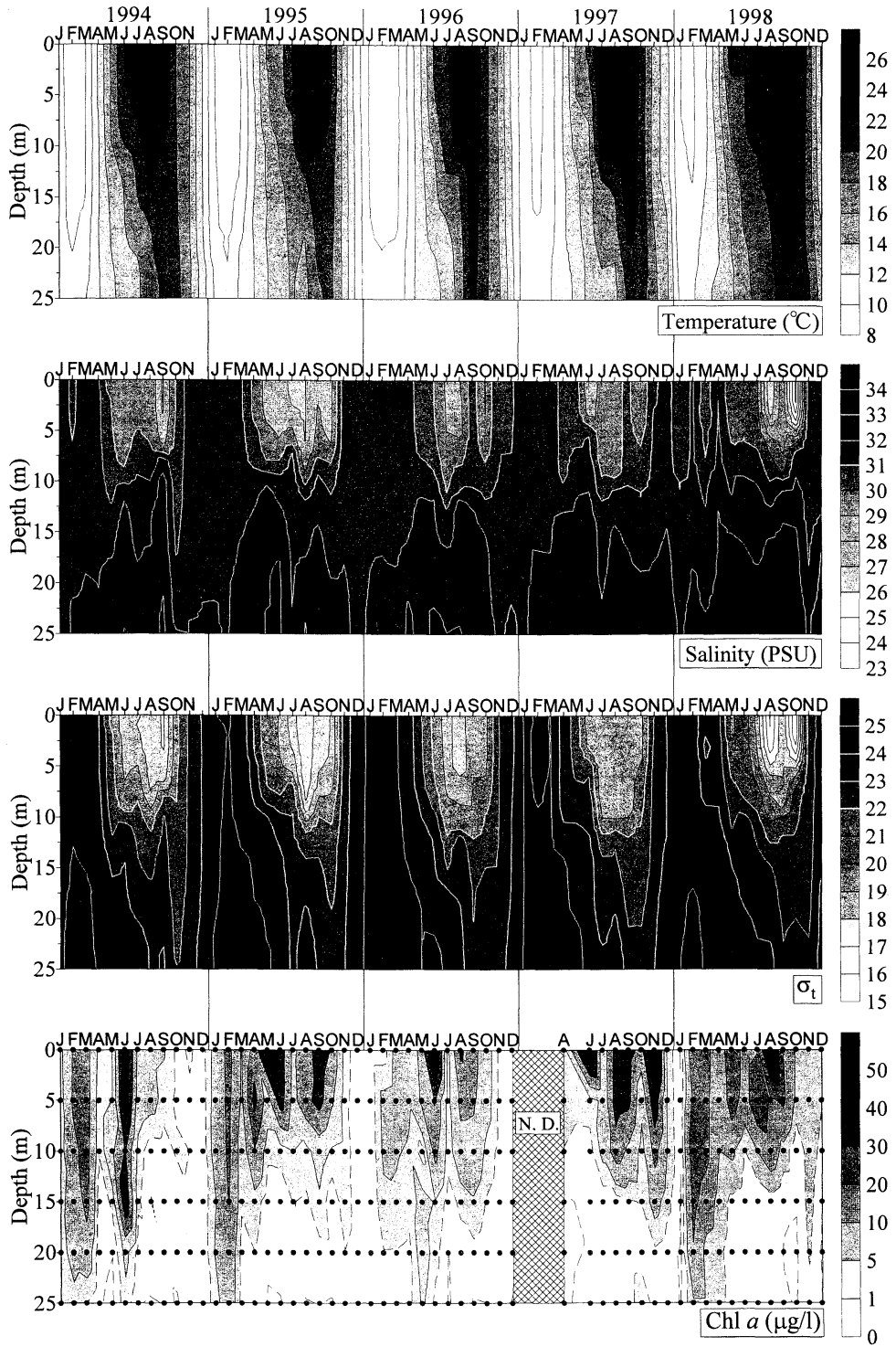


Fig. 3. Seasonal variation in vertical distribution of Temperature, Salinity, Sigma-t and Chl *a* at station F6 in Tokyo Bay from January 1994 to December 1998. N. D. = No data.

F3 では 1994 年 3, 9 月, 1995 年 6 月, 1996 年 8 月に, Sta. F6 では 1994 年 6, 9 月, 1995 年 5, 6 月, 1996 年 4, 6, 7, 8 月に見られたが, 1997 年以降は見られなかった。

表層の水温・塩分を両測点について比べると, 多摩川河口に近く陸水の影響を受けやすいと考えられる Sta. F3 の方が水温は夏季には高く, 冬季には低く, 塩分は周年にわたり低かった。

以上のような水温・塩分の変動を反映して, 顕著な密度躍層が 4 月頃以降 10 m 層以浅に形成された。密度躍層は 11 月以降急速に衰退し, 混合層の深度は冬季には大きくなるものの, 水温構造からみていずれの年も海底に達することはなかった。表層と底層との密度差は 1 月を中心に小さくなったが, 1997 年秋季から 1998 年冬季にかけては全体的に表層の塩分が低く, 表層と底層の密度差がやや大きかった。

表層の Chl *a* 濃度は Sta. F3 では 0.9–122 $\mu\text{g/l}$, Sta. F6 では 0.9–57.2 $\mu\text{g/l}$ の間で変動した。成層が発達している春季から初秋 (4 月–10 月) には表層で濃密に, 密度躍層が深で非常に低濃度になる傾向にあり, 成層が弱く混合層が海底近くに達する冬季 (11 月–3 月) には水柱全体にほぼ均一に分布した。これは山口・有賀 (1988) が, Chl *a* の濃度分布は基本的に水温等の物理的パラメーターに対応して, 夏季の成層期には表層で著しく高く, 冬季は比較的低濃度で上下一様の分布様式を示すと述べていることと一致する。野村 (1995) は東京湾では 1986 年以降 Chl *a* の平均濃度は変化しないものの最高値が経年的に低下していると述べている。本研究では Chl *a* が 100 $\mu\text{g/l}$ を越える高濃度を記録したのは 1996 年の Sta. F3 表層のみで, それ以外では高くても 60 $\mu\text{g/l}$ 程度であり, 高濃度の Chl *a* が見られない傾向が依然として継続しているようである。各年の Chl *a* 濃度の最高値は成層期に見られるが, 1997 年は例外的に 11 月に Chl *a* 濃度が最高になった。

3-2 栄養塩濃度の季節変動

1994 年 1 月から 1998 年 12 月にかけての Sta. F3 および Sta. F6 における $\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NH}_4\text{-N}$, $\text{PO}_4\text{-P}$ および $\text{Si(OH)}_4\text{-Si}$ の季節変動をそれぞれ Fig. 4 および Fig. 5 に示す。

$\text{NO}_3\text{-N}$ は Sta. F3 表層で 3.0–63.8 μM , 底層で 0.09–35.7 μM , Sta. F6 では表層で 0.2–38.8 μM , 底層で 1.2–30.1 μM の間で変動した。表層・底層ともに 8 月頃を中心に夏季に低濃度になり, 1 月頃を中心に冬季に高濃度になる傾向にあった。

$\text{NO}_2\text{-N}$ は Sta. F3 表層で 0.6–9.7 μM , 底層で 0.02–8.0 μM , Sta. F6 では表層で 0.3–6.7 μM , 底層で 0.4–6.2 μM の間で変動した。表層・底層ともに 8 月頃を中心に夏季に低濃度になり, 1 月頃を中心に冬季に高濃度になり, $\text{NO}_3\text{-N}$ と同様の変動を示した。

$\text{NH}_4\text{-N}$ は Sta. F3 表層で 0.7–70.0 μM , 底層で 0.2–37.9 μM , Sta. F6 では表層で 0.2–32.5 μM , 底層で 1.0–21.5 μM の間で変動した。表層では 7 月頃を中心に低濃度になり, 1 月頃を中心に高濃度になった。底層では Sta. F6 では表層と同様の季節変動を示したが, Sta. F3 底層では冬季とともに夏季にも比較的高濃度になった。

$\text{PO}_4\text{-P}$ は Sta. F3 表層で 0.1–2.8 μM , 底層で 0.5–4.1 μM , Sta. F6 では表層で 0.03–1.9 μM , 底層で 0.5–3.0 μM の間で変動した。表層では 6 月頃を中心に低濃度に, 12 月頃を中心に高濃度になっていた。底層では逆に 2, 3 月を中心に低濃度になり, 8 月を中心に夏季に非常に高濃度になった。

$\text{Si(OH)}_4\text{-Si}$ は Sta. F3 表層で 1.2–12.9 μM , 底層で 1.1–84.4 μM , Sta. F6 では表層で 0.7–56.4 μM , 底層で 1.1–58.7 μM の間で変動した。表層では 2 月頃に最も低濃度になり, 10 月頃に最も高濃度になった。年によっては 4 月から 9 月の成層期に一時的に低濃度になることがあった。底層では 2 月頃に表層と同様に低濃度となり, 7, 8 月に高濃度となった。

塩分のところで述べたように, 1998 年の 10 月は淡水流入の増大のため, 表層で $\text{NO}_3\text{-N}$, $\text{PO}_4\text{-P}$, $\text{Si(OH)}_4\text{-Si}$ が高濃度で特に Sta. F3 顕著であった。

Fig. 6 に 1994 年 1 月から 1998 年 12 月にかけての Sta. F3, F6 における DIN/DIP 比 ($\text{DIN} = \text{NO}_3\text{-N} + \text{NO}_2\text{-N} + \text{NH}_4\text{-N}$, $\text{DIP} = \text{PO}_4\text{-P}$) および DSi/DIN 比 ($\text{DSi} = \text{Si(OH)}_4\text{-Si}$) の変動を示す。全海洋における DIN/DIP 比や海洋植物プランクトン細胞の N/P 比は平均で 16 の値を示すことが知られている (REDFIELD *et al.*, 1963)。表層の DIN/DIP 比は冬季を中心に 16 を大きく上回る高い値を示し, 夏季に 16 前後の値を示す傾向が見られた。ただし, 1995 年の夏季は例外的に高い値で推移した。底層の DIN/DIP 比は表層同様の季節変動を示したが, 値は表層より低く, 特に底層の $\text{PO}_4\text{-P}$ 濃度が非常に高くなる夏季には毎年 16 以下の値が数ヶ月継続した。

一般的に海水中の DIN/DIP 比が 16 より高いときは植物プランクトンの増殖にとってリンが, 16 より低いときは窒素が制限要因となる可能性があるといわれている (例えば, 佐々木, 1991; 魚ほか, 1995)。本研究の結果について見ると, DIN/DIP 比は両測点とも夏季の一時期を除いて 16 を大きく上回っていた (Fig. 6)。これは, 東京湾では流入負荷における N/P 比が佐々木 (1991) の試算では 34, 高田 (1993) の試算では 27 と高く, さらに湾内の植物プランクトンが窒素・リンを REDFIELD 比に近い割合で取り込んだ結果, リンが先に枯渇するため (魚ほか, 1995) と考えられる。夏季に DIN/DIP 比が 16 前後の値を示すのは, 後に述べるように夏季には底泥からの溶出によるリンの負荷があるためと考えられる。しかし, DIN 濃度は最低でも Sta. F3 で 5 μM 以上, Sta. F6 で 2 μM 以上はあり, 周年枯渇することはない, DIN が植物プランクトンの増殖を律速することはほと

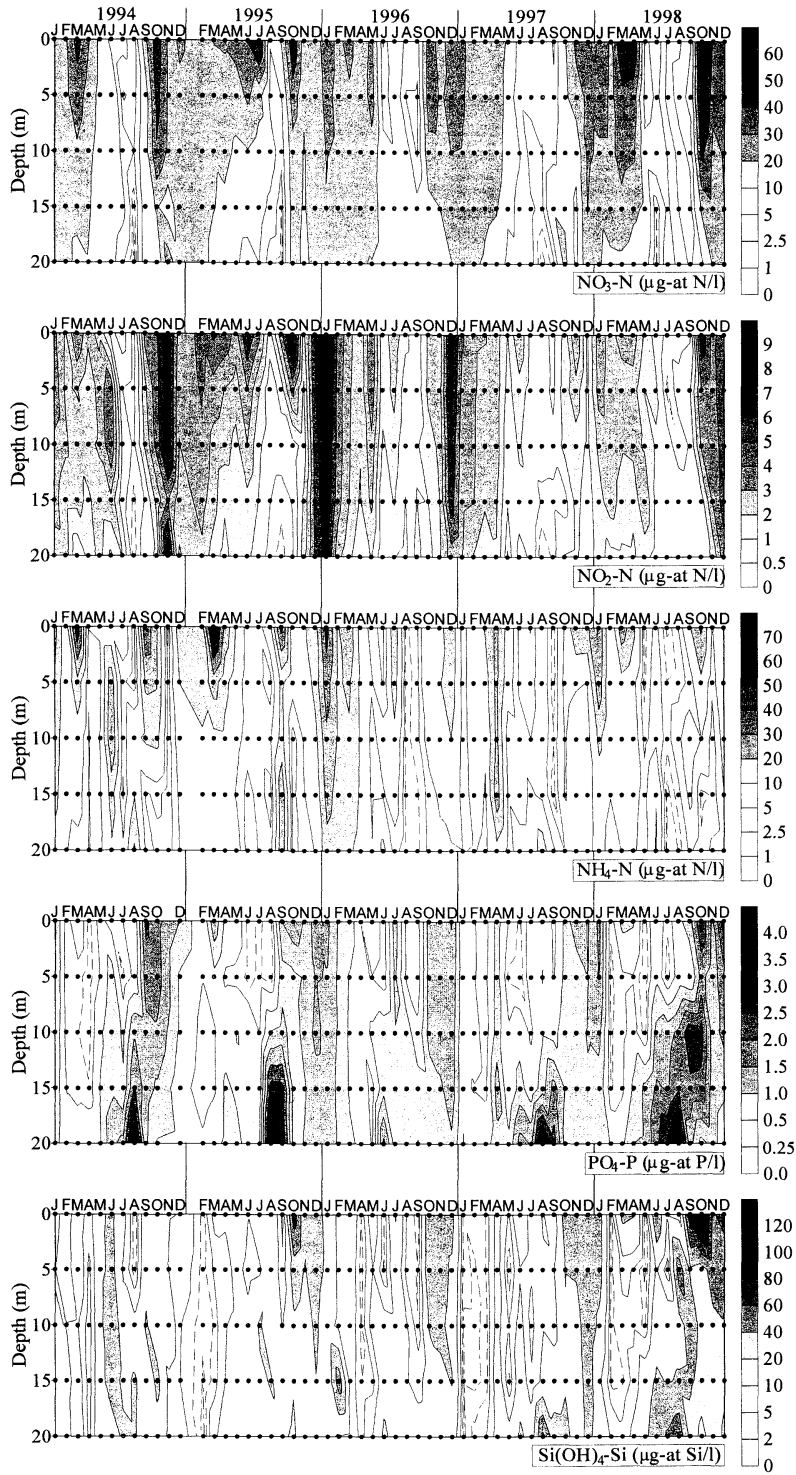


Fig. 4. Seasonal variation in vertical distribution of NO₃-N, NO₂-N, NH₄-N, PO₄-P and Si(OH)₄-Si at station F3 in Tokyo Bay from January 1994 to December 1998.

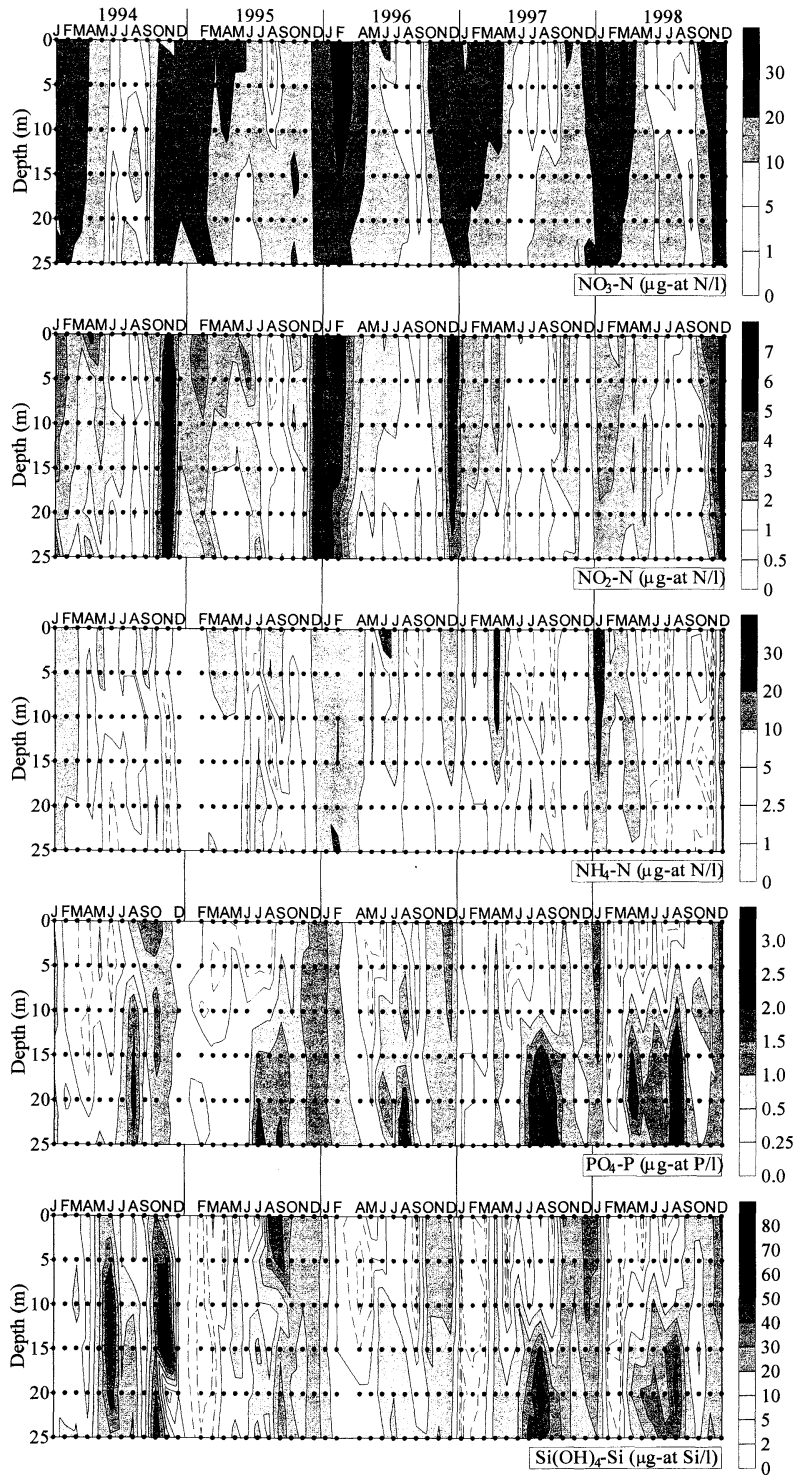


Fig. 5. Seasonal variation in vertical distribution of NO₃-N, NO₂-N, NH₄-N, PO₄-P and Si(OH)₄-Si at station F6 in Tokyo Bay from January 1994 to December 1998.

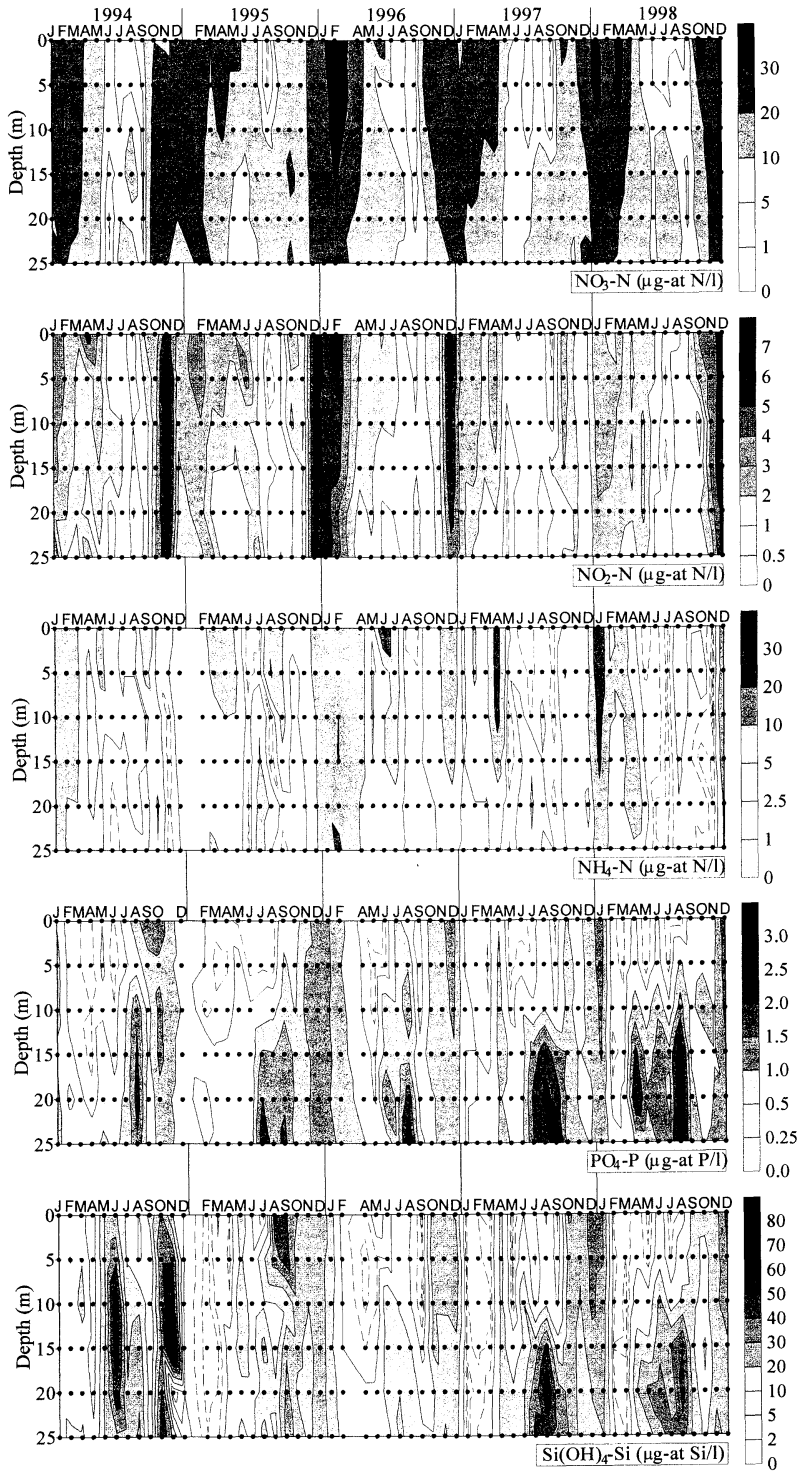


Fig. 6. Seasonal variation in vertical distribution of DIN/DIP (DIP=PO₄-P) and DSi/DIN (DSi=Si(OH)₄-Si) at station F3 and F6 in Tokyo Bay from January 1994 to December 1998.

んどないと思われる。

表層における $\text{Si}(\text{OH})_4\text{-Si}$ 濃度は冬季に低く、夏季に高くなる季節変動を示した (Fig. 4, 5)。野村・吉田 (1997) は、東京湾の植物プランクトン群集は 1-3 月の冬季には珪藻類の割合が高く、春季から秋季の 4-12 月には鞭毛藻類の割合が高くなると述べている。したがって、冬季に $\text{Si}(\text{OH})_4\text{-Si}$ 濃度が低いのは珪藻類の増殖により取り込まれるため、このことは 1995 年 2 月や 1998 年 2 月のように冬季でも比較的 Chl *a* 濃度が高く、珪藻類が大増殖していると思われる時に、 $\text{Si}(\text{OH})_4\text{-Si}$ が特に低濃度であることから示される (Fig. 2, 3, 4, 5)。夏季の Chl *a* 濃度が高く植物プランクトンが活発に増殖している時期に $\text{Si}(\text{OH})_4\text{-Si}$ 濃度が高いのは、珪藻が少なく $\text{Si}(\text{OH})_4\text{-Si}$ があまり利用されないためと考えられる。また、夏季には淡水流入量が増加し (宇野木・岸野, 1977)、それにともない栄養塩の流入量が増加すること、後述するが水温が高く底泥から珪素が溶解しやすくなることも挙げられる。

人為的影響や珪藻類のブルームなどにより水柱の DIN に対する $\text{Si}(\text{OH})_4\text{-Si}$ の割合が低下すると、珪藻の増殖にとって珪素不足となり、結果として鞭毛藻類が卓越すると言われている (OFFICER and RYTH, 1980; CONLEY and MALONE, 1992; DEL AMO *et al.*, 1997)。平均的な珪藻類の Si/N 比はほぼ 1 である (BRZEZINSKI, 1985) ことから、海水中の DSi/DIN 比が 1 以下になれば珪藻の増殖が律速される可能性が考えられる。表層の DSi/DIN 比は、珪藻類の卓越する冬季に 1 より低く、鞭毛藻類が卓越する夏季に 1 より高いことが多かった。また、珪藻は $\text{Si}(\text{OH})_4\text{-Si}$ の濃度が $2 \mu\text{M}$ 以下になると他の藻類との競合に打ち勝つことができると言われる (EGGE and AKENES, 1992)。本調査の 10 年間で、珪藻の現存量が低くなる 4-12 月に $2 \mu\text{M}$ 以下の $\text{Si}(\text{OH})_4\text{-Si}$ 濃度が見られたのは Sta. F3 では 1990 年 8 月、1994 年 8 月のみであり、Sta. F6 では 1990 年 9 月、1991 年 7 月、1996 年 9 月、1997 年 5 月、1998 年 7 月とあまり多くなく、東京湾において $\text{Si}(\text{OH})_4\text{-Si}$ が濃度の面で珪藻類の増殖を制限することはまれであると考えられる。以上のことから東京湾では、 $\text{Si}(\text{OH})_4\text{-Si}$ 濃度が低く DSi/DIN 比が低い冬季に珪藻類が卓越し、 $\text{Si}(\text{OH})_4\text{-Si}$ 濃度が高く DSi/DIN 比が比較的高いにもかかわらず夏季には珪藻類が少なく鞭毛藻類が卓越することがわかる。噴火湾では春季の珪藻ブルームにより珪素が枯渇し、鞭毛藻への遷移がおこると言われる (TSUNOGAI and WATANABE, 1983) が、東京湾においては、珪藻の衰退は $\text{Si}(\text{OH})_4\text{-Si}$ 濃度の低下よりも、鞭毛藻類との光の競合など他の要因によっていると考えられる。

底層における各栄養塩の季節変動についてみると、 $\text{NO}_3\text{-N}$ 、 $\text{NO}_2\text{-N}$ については夏季に低濃度、冬季に高濃度で、 $\text{NH}_4\text{-N}$ は冬季のみでなく夏季にも比較的高濃度であった。 $\text{PO}_4\text{-P}$ 、 $\text{Si}(\text{OH})_4\text{-Si}$ は夏季に高濃度で冬季に

低濃度であった (Fig. 4, 5)。

底層水の栄養塩濃度は底質中の有機物の分解の影響を受けると考えられる。また有機物の分解は水温が高いほど促進され、よって夏季に底層の栄養塩濃度が高くなると予想されるが、 $\text{NO}_3\text{-N}$ 、 $\text{NO}_2\text{-N}$ 濃度は高くはない。有機態窒素が無機態の窒素に分解されるには、まず $\text{NH}_4\text{-N}$ の形で水中に放出され、また $\text{NH}_4\text{-N}$ は好氣的な環境下では硝化細菌により、 $\text{NO}_2\text{-N}$ 、 $\text{NO}_3\text{-N}$ へと酸化される (才野, 1985)。東京湾では夏季、底層水が貧酸素化あるいは無酸素化することが知られており (風呂田, 1988)、したがって $\text{NH}_4\text{-N}$ 濃度が高く $\text{NO}_2\text{-N}$ 、 $\text{NO}_3\text{-N}$ 濃度が低いのは、嫌氣的な環境下で $\text{NH}_4\text{-N}$ が $\text{NO}_2\text{-N}$ や $\text{NO}_3\text{-N}$ に酸化されにくいとみられる。

有機物が分解されると $\text{NH}_4\text{-N}$ と $\text{PO}_4\text{-P}$ は REDFIELD 比に近い割合で生じる (REDFIELD *et al.*, 1963) が、夏季底層水中の $\text{PO}_4\text{-P}$ は $\text{NH}_4\text{-N}$ に比べて著しく高濃度である。 $\text{PO}_4\text{-P}$ は酸化的環境下では底泥中の鉄水酸化物に吸着され、還元的環境下では溶脱することが知られている (才野, 1985)。夏季に見られる底層の高い $\text{PO}_4\text{-P}$ 濃度は、 $\text{PO}_4\text{-P}$ が有機物の分解により生じるとともに、底層水の貧酸素化により底質から溶出したためと考えられる。

また底泥からの珪素の溶解は水温の上昇により促進されることが知られている (YAMADA and D'ELIA, 1984)。したがって、水温の高い夏季に珪素の溶解が活発になり、高濃度の $\text{Si}(\text{OH})_4\text{-Si}$ が底層で見られると考えられる。

神山ほか (1998) は夏季播磨灘における底泥からの栄養塩の負荷は、陸上からの負荷に比べて DIN、 $\text{PO}_4\text{-P}$ 、 $\text{Si}(\text{OH})_4\text{-Si}$ でそれぞれ 82, 79, 250% であると述べている。東京湾において底泥からの栄養塩の負荷を見積もった例は珪素については見当たらないが、一年間の陸上からの負荷に対して窒素では 15%、リンで 38% といわれている (環境庁水環境研究会編, 1996)。従来、東京湾では流入負荷中のリンの割合は窒素に比べ低く、有機物の内部生産を抑えるためには、リンの流入負荷を削減することが効果的であると言われてきた (佐々木, 1991)。しかし、リンは夏季に底泥から大量に溶出しており、枯渇しない窒素とともに、内部生産をさらに助長すると考えられる。東京湾の環境回復のためには貧酸素水塊が発生しないレベルまで窒素、リンの流入負荷を抑える必要がある。

3-3 1989-1998年にかけての栄養塩濃度の経年変動

Fig. 7 および Fig. 8 にそれぞれ Sta. F3 および Sta. F6 表層における 1989-1998 年にかけての DIN、 $\text{PO}_4\text{-P}$ 、 $\text{Si}(\text{OH})_4\text{-Si}$ 、DIN/DIP 比、DSi/DIN 比の変動を示す。1 ヶ月内に 2 回調査を行った 1992 年 8 月については、2 回の調査のデータを平均して用いた。図中の曲線は各項目の 12 ヶ月移動平均を示し、直線は 12 ヶ月移動平均したデータをもとに最小二乗法により求めた回帰直線を示す。また、コックス・スタートの検定を用いて、危険

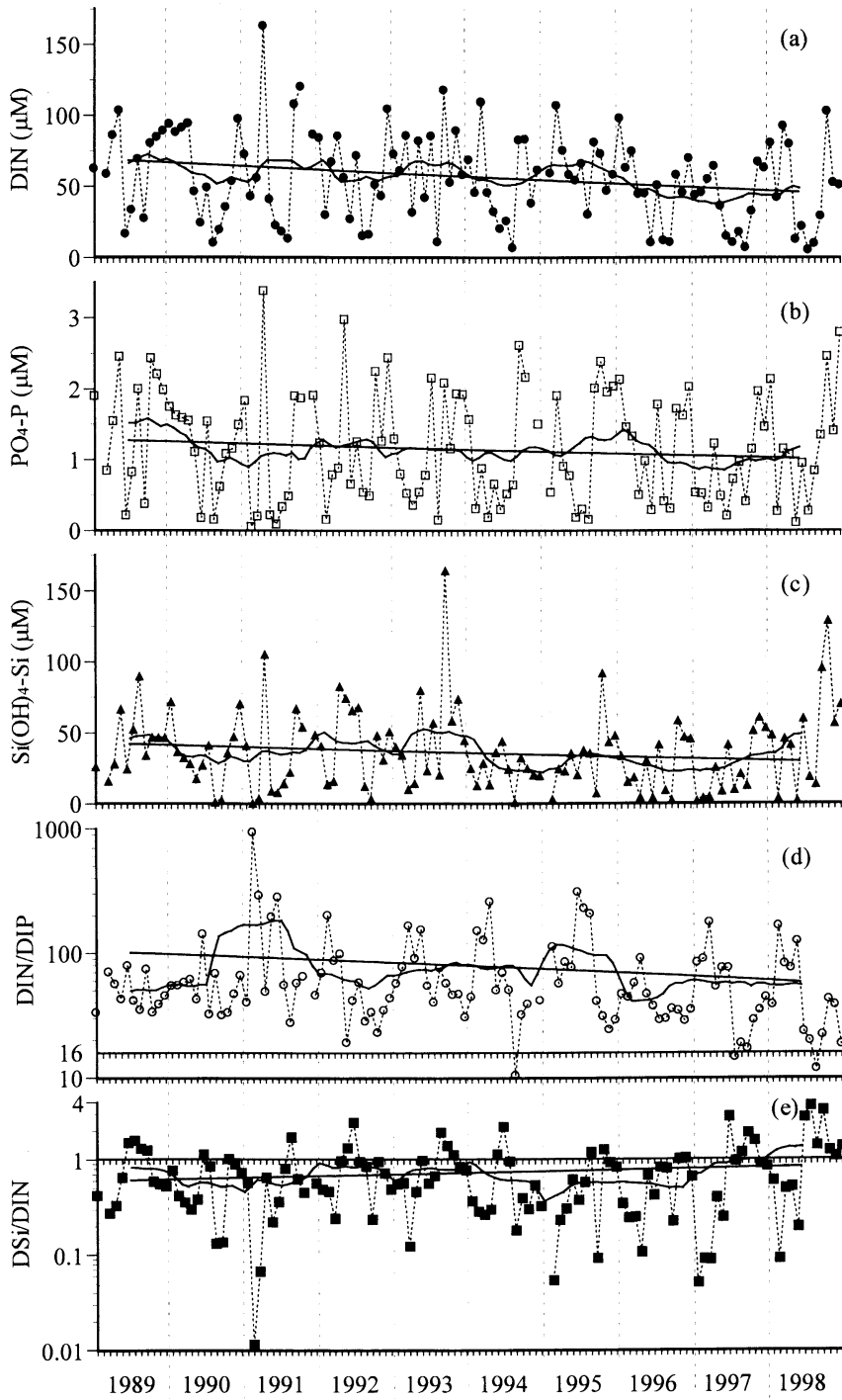


Fig. 7. Yearly variation of surface DIN (a), $\text{PO}_4\text{-P}$ (b), $\text{Si(OH)}_4\text{-Si}$ (c), DIN/DIP ($\text{DIP}=\text{PO}_4\text{-P}$) (d) and DSi/DIN ($\text{DSi}=\text{Si(OH)}_4\text{-Si}$) (e) at station F3 in Tokyo Bay from January 1989 to December 1998. Curve lines denote 12-months running mean during 1989 to 1998. Straight lines denote the trends for 1989 to 1998 calculated by least-squares method.

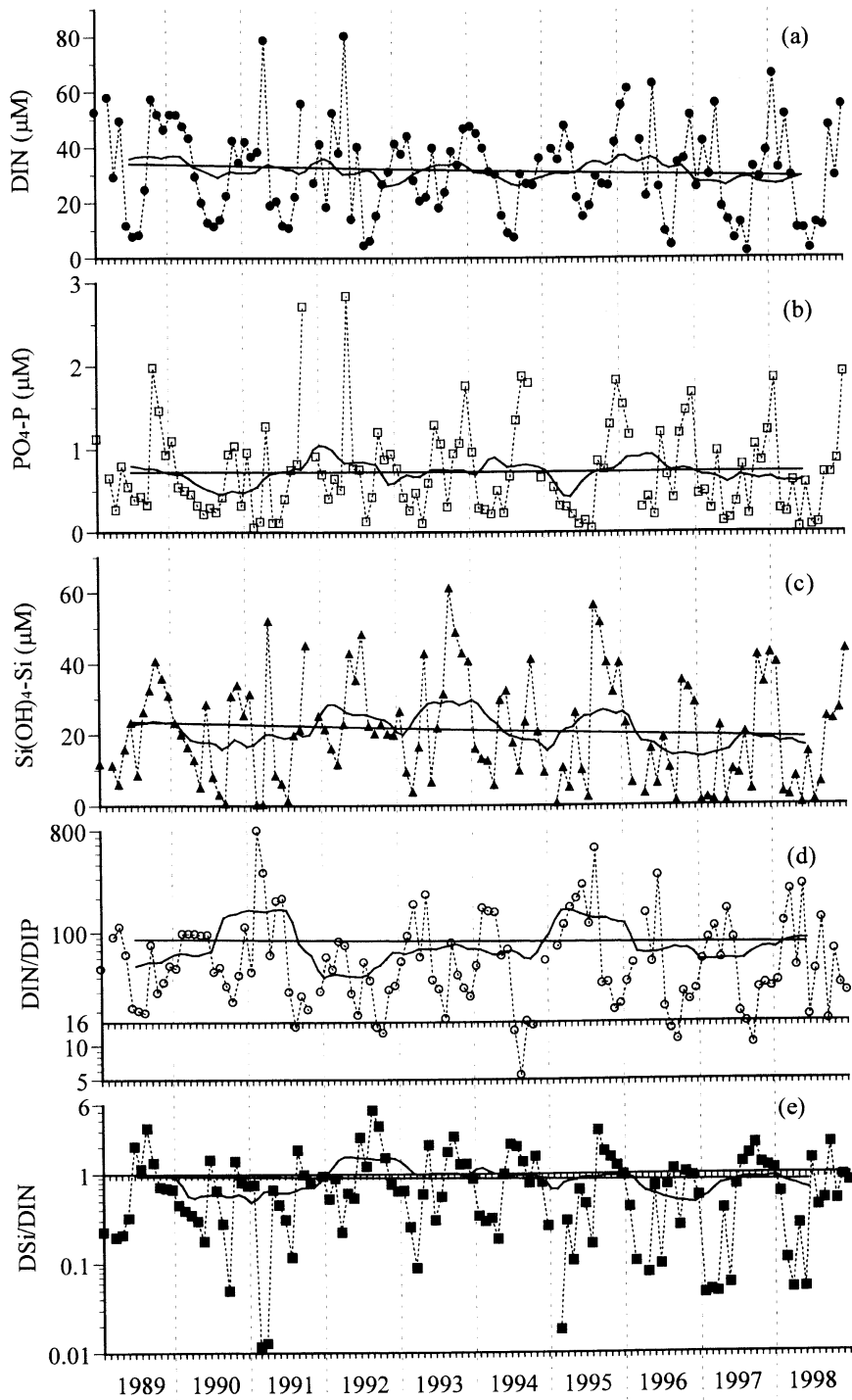


Fig. 8. Yearly variation of surface DIN (a), $\text{PO}_4\text{-P}$ (b), $\text{Si(OH)}_4\text{-Si}$ (c), DIN/DIP ($\text{DIP}=\text{PO}_4\text{-P}$) (d) and DSi/DIN ($\text{DSi}=\text{Si(OH)}_4\text{-Si}$) (e) at station F6 in Tokyo Bay from January 1989 to December 1998. Curve lines denote 12-months running mean during 1989 to 1998. Straight lines denote the trends for 1989 to 1998 calculated by least-squares method.

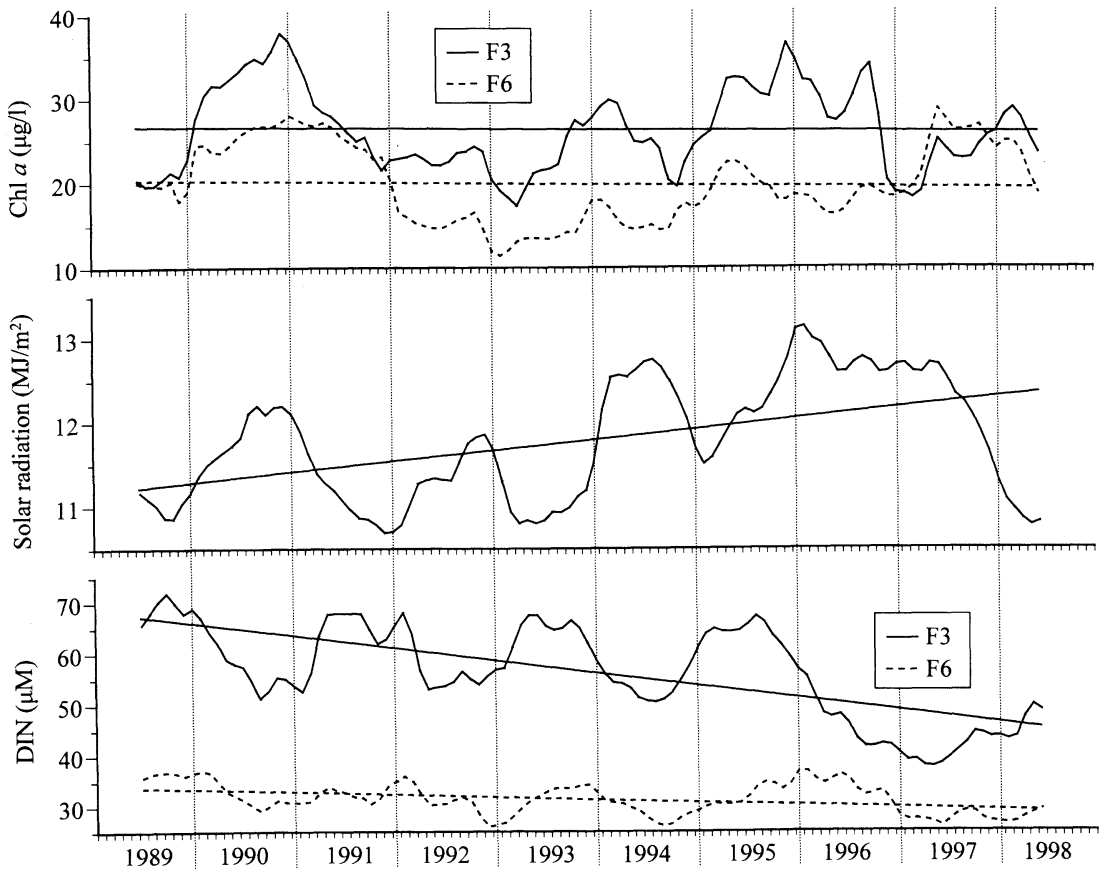


Fig. 9. Time series of 12-months running mean of surface Chl *a* at station F3 and F6 (top), solar radiation at Tokyo (middle) and surface DIN at station F3 and F6 (bottom) from 1989 to 1998. Straight lines are the trends for 1989 to 1998 calculated by least-squares method.

率 $\alpha = 0.05$ として上昇、下降のトレンドの有無を調べた。その結果、Sta. F3 の DIN, $\text{Si}(\text{OH})_4\text{-Si}$, DIN/DIP 比および Sta. F6 の $\text{Si}(\text{OH})_4\text{-Si}$ について減少の傾向が有意に認められた。

Sta. F3 の DIN/DIP 比が減少したのは DIN が減少したためと考えられる。しかし DIN/DIP 比は下がったとはいえ、調査期間を通じて Readfield 比の 16 よりも高い値を示すことがほとんどであり、また、先に述べたように DIN は枯渇することはなく、依然として高い濃度レベルで存在しているといえる。

DSi/DIN 比には両測点ともに 10 年間を通して、トレンドが認められなかった。Sta. F6 の DIN 濃度についても統計的に有意ではなかったが若干減少の傾向が認められたことから、DIN, $\text{Si}(\text{OH})_4\text{-Si}$ 濃度がともに下降したことが原因である。

KAWABE and KAWABE (1997b) は 1980-1989 年にかけての 10 年間で東京湾における COD の濃度は減少したことを報告しており、その理由は全天日射量が減少し

植物プランクトンの増殖が抑えられたためであると述べている。また、植物プランクトンによる摂取量の低下により、湾内の DIN 濃度が増加したと述べている。本研究の結果では 1989-1998 年にかけて、DIN 濃度が Sta. F3 では有意に減少し、Sta. F6 では統計的に有意ではなかったがわずかながら減少する傾向が見られた。本研究では COD については調査していないが、KAWABE and KAWABE (1997a) によれば、東京湾では COD と Chl *a* 濃度との間には相関係数 $r = 0.80$ と高い相関があることがわかっているので、1989-1998 年にかけての Chl *a* 濃度と全天日射量について調べてみた。全天日射量のデータは「気象要覧」の東京における各月の平均全天日射量(気象庁, 1989-1998)を用いた。結果を Fig. 9 に示す。また、Fig. 7, 8 同様に 12 ヶ月の移動平均、回帰直線を求め、トレンドの有無の検定を行った。全天日射量は 10 年間で増加しており、有意に上昇傾向が認められた。しかし、Chl *a* 濃度については横ばいで変動は認められず、DIN 濃度が減少した理由について、植物プランク

トンの増減から説明することはできなかった。DIN 濃度減少の理由としては下水道の普及や污水处理場の能力の向上などが考えられるが、はっきりとした原因については現在のところ不明である。

Si(OH)₄Si 濃度は両測点とも有意に減少傾向が認められた (Fig. 7, 8)。野村 (1995) は 1990 年まで東京湾の Si(OH)₄Si 濃度が減少した理由として、埋め立てにより砂浜から海域への供給が減少したこと、ダム建設によりダム湖内の珪藻に消費されること、河川改修により川底からの溶出が減少したことなどを挙げている。1989 年以降東京湾岸での埋め立てや流域での河川工事がどの程度行われたか、本研究では調べていないが、Si(OH)₄Si 濃度が減少した理由の 1 つであると考えられる。

2000 年度から 2004 年度に向けて、第 5 次水質総量規制が実施されており、規制項目として従来の COD に加えて新たに N, P が追加された。N, P 流入負荷の削減が東京湾の栄養塩濃度にどのように反映するのか、今後の動向を調べて行きたい。

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Étude bibliographique

Prof. Luigi SANZO: a bibliographic revision with ichthyological notes

Kazunori TAKAGI*

Abstract : The bibliography of Luigi SANZO (1874–1940) is revised by reading available basic references including unpublished sources. His works cover a broad range of zoology-related fields, but his main interest apparently focuses on marine biology represented by early life history of teleostean fishes, bathyal and neritic. He published totally 122 works during the period from 1900 to 1940. Through such activities, looks unique his interest shown in a monograph (1911) on comparative morphology of 17 gobiid fishes. The origin of the interest is inferable from his academic career.

Résumé: La bibliographie de Luigi SANZO (1874–1940) est revue par la lecture avec soin de renseignements fondamentales disponibles, y compris des bonnes sources non publiées. Ses ouvrages embrasse le champ étendu concernant à zoologie, mais son premier intérêt était évidemment concentré sur biologie marine, surtout le premier cycle biologique des téléostéens bathyaux et aussi néritique. M. SANZO a publié un total de 122 ouvrages pendant 41 ans depuis 1900 jusqu'à 1940. Dans sa toute activité académique durant, il a montré son unique intérêt par un monographie (1911) sur morphologie comparée de 17 espèces de gobie. La particularité de cet ouvrage peut être inférée d'une carrière académique dans sa vie.

Key words : *words:Luigi SANZO, bibliography, ichthyology*

1. Introduction

Prof. Luigi Sanzo (Capizzi, 1874–Messina, 1940) was a Messinese marine biologist with indefatigable enthusiasm for scientific research. His birth place is unexpectedly a small city rising 1146 m above sea level, and with 3899 inhabitants (as for 1985; after Tour. Club Ital., 1996) among the Nebrodi Mountains in Messina Province, Italy. The mountain life in this city, however, was not necessarily independent from the sea. Capitinean boys of other days used to go down for eel fishing as far as Aquedolci (more than 50 Km distant from Capizzi) on the Tyrrhenian coast. (Mainone M. Salvatore, pers. commun.)

According to SPARTÀ (1941), he studied first

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pharmacology at the Regia Università di Messina, directed by Prof. G. GAGLIO, and did his degree in medicine and surgery in 1899, and soon afterward (in 1901) a degree in natural sciences. His career was completely shifted from medical fields to zoological ones in 1907, when he was nominated as Lecturer and Assistant of comparative anatomy and physiology at the Istituto di Zoologia, Regia Università di Palermo. Afterwards, he devotedly kept working at marine biology, later (1916–1940) as Director at the Istituto Centrale di Biologia Marina in Messina, Regio Comitato Talassografico Italiano, actually the Istituto Sperimentale Talassografico, Consiglio Nazionale di Ricerche, Messina. (Appendix 1)

During 41 years from 1900 to 1940, Sanzo published 122 contributions in serial issues or in books. The total number of his works is

referred again later in detail. Basic source of his bibliography is given as the following two. One is a collection of reprints bound in 3 volumes (92 papers), and entitled "Luigi Sanzo Opere I to III (SOI-III). The 3-volume Works is deposited in the Istituto Sperimentale Talassografico, Messina. The other is a bibliography (125 entries; LS) compiled by SPARTÀ (1941). Following these two references, other two bibliographic references may be added to the source. One of them is the Clofnam bibliography sections (CL) compiled by HUREAU and MONOD (1973: 132-134; 46 entries) and by TORTONESE and HUREAU (1979: 390; 1 entry). The other is a set of unpublished reference cards (68 entries; SZ) for the library of the Stazione Zoologica "Anton Dohrn," Naples. The cards are of 11 sheets of 147 × 175 mm in size, and with the headings of "Luigi Sanzo" (10 sheets) or "Sanzo, L. & Pirrone, F." (1 sheet).

To reading carefully those four basic sources, libraries deposited in Italy and France has been referred, as much as possible. Such libraries are of:

Museo Civico di Storia Naturale "Giacomo Doria" (BMD), Genova; Istituto Idrografico Marina (BII), Genova; Bibliothèque Centrale (BCM) and Laboratoire d'Ichthyologie Générale et Appliquée (LIM; reprint collection) of the Museum National d'Histoire Naturelle, Paris.

Results of our revision are enlisted in the Section 2, below, and some related topics are summarized in the succeeding sections. Our report was partly illustrated at the annual meetings (poster session) for 1997 and 1999 of the Ichthyological Society of Japan.

2. Annotated bibliography of L. SANZO

The 122 entries contained here are each composed of three parts or paragraphs as given as follows, while the third one is occasional.

A. Bibliographic elements

This is the first paragraph, that is, the main body of each entry. The elements may be shown in the following three categories.

(i) Publication date, or entry code, with a supplementary letter (a, b, c,...), if necessary: this listing is arranged principally in chronological order (by year), but at random within

the framework of the publication year, unless any reliable reason is provided;

(ii) Text title: it is accompanied with its tentative translation in English in brackets, when the title is in Italian; it is noted here that this report relates generally to the text title, but not to the body of text, unless otherwise stated;

(iii) Other elements for serials and books: their title is generally described in full; pagination of the text in serials is given as that in original issue, as far as possible; in cases, it may be of reprints.

B. Bibliographic annotation

The second paragraph of each entry is primarily for the registration of sources read for our survey. Second, it is for any difference in the elements, if any, between the registered description shown in the first paragraph (Paragraph A, above) and concerned element in references. Cross references may be given here, if necessary.

The references and their abbreviation are mentioned above, in the section of introduction. They are alphabetically summarized as index by abbreviation on the following lines.

BCM: libraries deposited in the Bibliothèque Centrale, MNHN, Paris;

BII: one of libraries deposited in the Istituto Idrografico Marina, Genova;

BMD: libraries deposited in the Museo Civico di Storia Naturale "Diacomo Doria," Genova;

CL: entries of the Clofnam bibliography sections;

LIM: reprint collection deposited in the Laboratoire d'Ichthyologie Générale et Appliquée, MNHN, Paris;

LS: entries of the "Publicazioni di Luigi SANZO" in SPARTÀ (1941); entry number (1-125) is given here in parentheses;

SOI-SOIII: reprint collection in three volumes deposited in the Istituto Sperimentale Talassografico, Messina; Sanzo Opere I (46 papers), Sanzo Opere II (35 papers) and Sanzo Opere III (10 papers); each volume is indexed in numerical code; the code number is given here in parentheses;

SZ: entries of the reference cards for the Stazione Zoologica "Anton Dohrn," Naples; sheet number (1-10) is given here in

parentheses.

C. Taxonomic comments

The taxonomic state of taxa referred by SANZO at that time may frequently be out of the application from the today's criterion of taxonomy. The third paragraph is for the

synonym problem on taxa referred in the text title. Such species are shown here with their revised name(s) always from the standpoint of the Clofnam (1973). Cross references may be given, if necessary.

Bibliography of Luigi SANZO

- 1900 Sull'acido carbonico quale uno dei fattori della fatica muscolare. [On carbonic acid as one of the factors of muscular fatigue.] Volume in omaggio a Prof. Luciani. «Ricerche di fisiologia e scienze affini». Milan: Società Editorice Libraria. 12 p.+3 pls.
SOI(1); LS(1); SZ(1) [Pagination] 2 p., 1 fig., 3 pls.
- 1903a Sur un processus d'inhibition dans les mouvements rythmiques des méduses. Archives Italiennes de Biologie, Torino, **39 (3)**: 319-324.
SOI(3); LS(8); SZ(1) [Text pagination] 8 p.; BCM.
- 1903b Su di un processo d'inibizione nei movimenti ritmici delle meduse. [On a process of inhibition in the rhythmical movements of jellyfishes.] Rivista di Biologia Generale, Torino, **5 (3)**: 1-6, pls. 1-3.
SOI(2) [Text pagination] may be of the reprint issue; LS (2) [Publication date] not cited; SZ(1) [Publication date] 1905.
- 1904a Trasformazione sperimentale delle uova lecitiche diffuse in uova telelecitiche e susseguente modificazione della segmentazione uguale in segmentazione oloblastica disuguale. [Experimental transformation from diffused lecithal eggs into telelecithal eggs and the following modification from regular segmentation to irregular holoblastic segmentation.] Ricerche fatte nel Laboratorio di Anatomia Normale della R[eale] Università di Roma ed in altri laboratori biologici **10 (3)**: 263-272, 4 figs., pl. 16.
SOI(7); LS(5); SZ(1); BCM
- 1904b Tre nuovi metodi per fissare e ritrovare al microscopio un punto qualunque di un preparato. [Three new methods in order to fix and run in the microscope any point of a preparation.] Zeitschrift für wissenschaftliche Mikroskopie und für mikroskopische Technik, Leipzig, **21 (1)**: 27-46, figs. 1-15.
SOI(5); LS(10); SZ(1); BCM
- 1905a Apparecchio utile in embriologia per la fissazione automatica a tempi voluti di embrioni in viadi sviluppo. [Useful instruments in embryology for automatic fixation at desired times of developing embryos.] Zeitschrift für wissenschaftliche Mikroskopie und für mikroskopische Technik, Leipzig, **21 (4)**: 449-457, figs. 1-4.
SOI(4); LS(9) [Publication date] 1904, may be confused with a business term; SZ(2); BCM. This paper was "eingegangen am 9. Januar 1905".
- 1905b Uova e larve di Murenoidi. [Eggs and larvae of muraenoids.] Atti della R[eale] Accademia Peloritana **19 (2)**: 1-7.
SOI(6) [Text pagination] in reprint issue; LS(3) [Publication date] 1904; may be confused with the date of meeting (3 December 1904); SZ not registered; CL [Text pagination] p. 311-315.
The Murenoidi may correspond to the suborder Anguilloidei. The following species are referred in this paper. According to SPARTÀ (1941 : 248), they should be *Nettastoma melanura* Rafinesque [= *Nettastoma melamurum* Rafinesque, 1810] and *Congromuraena mystax* of Günther, 1870 [= *Muraena mystax* Delarouche, 1809.] The latter is revised as *Gnathophis mystax* (Delarouche, 1809). According to the Clofnam, the referred species are *Muraena helena* Linnaeus, 1758, *Chlopsis bicolor* Rafinesque, 1810, and *Echelus myrus* (Linnaeus, 1785). (BLACHE, BAUCHOT and SALDANHA, 1973b, c, d, e, f)

- 1905c Sulle cause dell'attuale moria dei molluschi bivalvi coltivati nei laghi di Ganzirri e Faro (Messina). [On the causes of the current diseases of the bivalve molluscs cultivated in the lakes of Ganzirri and Faro (Messina).] Atti della R[eale] Accademia Peloritana **19** (2): 1-21, 1 pl.
 LS(11) [Serial issue number] not referred; SZ(1) [Text pagination] 21 p.; BCM. The above-mentioned text pagination may be of reprint issue.
- 1905d Impiego dell'elettrolisi nella impregnazione metallica e nella colorazione dei tessuti. [Use of electrolysis in metallic impregnation and coloration of tissues.] Atti della R[eale] Accademia Peloritana **19**: 1-3.
 SOI(8) [Text pagination] may be of reprint issue; LS(4); SZ (2).
- 1905e Particolare disposizione del sacco vitellino in un embrione di Selacide. [Particular disposition of the yolk sac in an embryo of selachians.] Atti della R[eale] Accademia Peloritana **19**: 1-2.
 SOI(9) [Text pagination] may be of reprint issue; LS(7); SZ not registered.
- 1905f Impiego dell'elettrolisi nella impregnazione metallica e nella colorazione dei tessuti. [Use of electrolysis in metallic impregnation and in coloration of tissues.] Anatomischer Anzeiger, Jena, **27**: 269-270.
 LS(6); SZ(2); BCM.
- 1907a Zur Kenntnis des Stickstoff-Stoffwechsels bei marinen wirbellosen Tieren. Biologisches Zentralblatt, Leipzig, **27**: 479-491, 1 fig.
 LS(12) [Publication date] 1905; SZ(2); BCM.
- 1907b Sul ritmo dei cuori di due larve di *Discoglossus*, saldate insieme. [On the heart rhythm of two larvae of *Discoglossus*, joined together.] Atti della [Reale] Accademia dei Lincei [5] Rendiconti **16** (1): 979-981.
 LS(14); SZ(2); BCM.
- 1907c Contrazioni ritmiche antiperistaltiche nell'intestino terminale di larve di *Discoglossus pictus*. [Rhythmic contraction of antiperistalsis in the terminal intestine of *Discoglossus pictus*.] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **16** (2): 149-151, fig. 1.
 SOI(10); LS(13); SZ(2); BCM.
- 1909a Uova e larve di *Auxis bisus*. [Eggs and larvae of *Auxis bisus*.] Monitore Zoologico Italiano, Florence, **20** (2-3): 79-80.
 SOI(11) [Publication date] 1908; LS(15); SZ(2); BMD.
 The *A. bisus* (Rafinesque) Morreau, 1881 (= *Scomber bisus* Rafinesque, 1810) is revised as *Auxis rochei* (Risso, 1810). (POSTEL, 1973a)
- 1909b Uova e larve di Scomberoidi. [Eggs and larvae of Scombroidei.] Bollettino del Ministero di Agricoltura Industria e Commercio [B] **8** (5): 86-87.
 SOI(12) [Publication date] 1908; LS (16); SZ not registered.
 The Scomberoidi in the text title may be translated as the suborder Scombroidei, but not the genus *Scomberoides* Lacepède, 1802. This inference is based on the text title of Entry [1910b].
- 1910a Studi sulla biologia del Tonno (*Orcynus thynnus* Ltkn). I. Uova pelagiche e periodo di maturità sessuale. [p. 1-4] II. Migrazioni batimetriche. [p. 4-7] III. Stadi giovanissimi d' *Orcynus thynnus* Ltkn., e identità tra questa specie e il *Thynnus brachypterus* C. V. [p. 7-15] [Studies on the biology of the bluefin tuna (*Orcynus thynnus* Lütken). I. Pelagic eggs and the period of sexual maturity. II. Bathymetric migrations. III. Youngest stages of *Orcynus thynnus* Lütken, and the identity between this species and *Thynnus brachypterus* Cuvier et Valenciennes.] Rivista Mensile di Pesca e Idrobiologia, Pavia, **5** (1): 1-15, figs. 1-3.
 SOI(15); LS(19); SZ(2); LIM; BMD. This paper includes three sections with their respective in-text subtitle, above.
 The *O. thynnus* of Lütken, 1880, and *T. brachypterus* Cuvier, 1832, in C. V. are either synonym of *Thunnus (Thunnus) thynnus* (Linnaeus, 1758); the genus *Orcynus* Cuvier, 1817, is a synonym of *Germo* Jordan, 1889. (POSTEL, 1973a)

- 1910b Uova e larve di Scomberoidi. Nota preliminare. I. Larva di Tonno (*Orcynus thynnus* Ltkn.) [p. 202] II. Uovo e larva di Palamida (*Pelamys sarda* C. V.) [p. 202–205, figs. 1–3] III. Uova pelagiche di Alalunga (*Orcynus germo* Ltkn.) [p. 205] [Eggs and larvae of Scombroidei. Preliminary note. I. Larvae of bluefin tuna (*Orcynus thynnus* Lütken). II. Eggs and larvae of a pelamid (*Pelamys sarda* Cuvier et Valenciennes). III. Pelagic eggs of albacore (*Orcynus germo* Lütken).] *Rivista Mensile di Pesca e Idrobiologia*, Pavia, **5** (7–9): 201–205, figs. 1–3.
SOI(13); LS(17); SZ(3); LIM. This paper includes the three sections with their respective in-text subtitle, above.
[Section 1] For the nomenclature of the *O. thynnus*, see Entry [1910a]. [Section 2] The *P. sarda* of Cuvier, 1832, in Cuv. Val. (= *Scomber sarda* Bloch, 1793) is revised as *Sarda sarda* (Bloch). (POSTEL, 1973b) [Section 3] The *O. germo* of Lütken, 1880, is a synonym of *Thunnus* (*Germa*) *alalunga* Bonnaterre, 1788. (POSTEL, 1973a) For the genus name *Orcynus*, see Entry [1910a].
- 1910c Uova e larve di pesce spada (*Xiphias gladius* L.) [Eggs and larvae of swordfish (*Xiphias gladius* Linnaeus).] *Rivista Mensile di Pesca e Idrobiologia*, Pavia, **5** (7–9): 206–209, figs. 1–2.
SOI(14); LS(18); SZ(2); CL; LIM; BMD.
- 1910d Uova e larve di Scomberoidi. [Eggs and larvae of Scombroidei.] *Bollettino del Ministero di Agricoltura Industria e Commercio* **2** [C] (12): 1–3.
SOI(16); LS(20); SZ not registered.
- 1911 Distribuzione delle papille cutanee (organi ciatiformi) e suo valore sistematico nei Gobi. [Distribution of the dermal papillae (cup-formed organs) and their systematic value in the *Gobius*.] *Mitteilungen aus der Zoologischen Station zu Neapel* **20** (2): 251–328, 15 figs., pls. 9–12.
SOI(17); LS(21); SZ(3) [pagination] p. 351 (clerical error)–328, 15 figs, 12 pls.; CL [Text pagination] p. 249–328.
- 1912a Comparsa degli organi luminosi in una serie di larve di *Gonostoma denudatum* Raf. [Appearance of the luminous organs in a series of larvae of *Gonostoma denudatum* Rafinesque.] *R[egio] Comitato Talassografico Italiano, Memoria* **9**: 1–23, 4 figs., 1 pl.
LS(22); SZ(3) [Pagination] 22 p., 1 pl.; CL; LIM; BMD.
- 1912b Larva di *Stomias boa* Risso. [Larva of *Stomias boa* Risso.] *R[egio] Comitato Talassografico Italiano, Memoria* **10**: 1–6, 1 pl.
SOII(1); LS(23); SZ(3); CL; LIM; BMD.
The *S. boa* of Cuvier, 1817, (= *Esox boa* Risso, 1810) is revised as *Stomias boa* (Risso). (MORROW, 1973b)
- 1912c Embrione di *Carcharodon Rondeletii* M. Hle. (?), con particolare disposizione del sacco vitellino. [Embryo of *Carcharodon rondeletii* Müller et Henle (?), with particular disposition of the yolk sac.] *R[egio] Comitato Talassografico Italiano, Memoria* **11**: 1–10, 2 pls.
SOII(2); LS(24) misprinted in the text title as Hb for Hle; SZ(3); LIM.
The *C. rondeletii* Müller et Henle, 1841, is a synonym of *Carcharodon carcharius* (Linnaeus, 1758). (SPRINGER, 1973)
- 1912d Uova di "Sternoptychidae" Gthr. [Eggs of Sternoptychidae Günther.] *R[egio] Comitato Talassografico Italiano, Bollettino Bimestrale* **2** (19): 384–386.
LS not listed; SZ(3) [Pagination] 5 p.; BMD.
- 1913a Larva di *Ichthyococcus ovatus* (Cocco). [Larva of *Ichthyococcus ovatus* (Cocco).] *R[egio] Comitato Talassografico Italiano, Memoria* **27**: 1–6, 1 pl.
SOII(3); LS(25) [Serial number] misprinted (17); SZ(4) cited without code nor pagination; CL [Pagination] 7 p., 1 pl.; LIM; BMD.
This species is effective to be *I. ovatus* Cocco, 1838, replacing *Gonostomus ovatus* Cocco, 1838. (WITZELL, 1973)
- 1913b Stadi post-embriionali di *Vinciguerria attenuata* (Cocco) e *V. Poveriae* (Cocco) Jordan ed Evermann. [Post-embryonic stages of *Vinciguerria attenuata* (Cocco) and *V. poweriae* (Cocco)

Jordan et Evermann.] R[egio] Comitato Talassografico Italiano, Memoria **35**: 1–8, 1 pl.

SOII(4); LS(26); SZ(4) cited without code nor pagination; CL [Text pagination] 7 p.; LIM.

The *V. poveriae* in the text title is misread for *V. poweriae*. (WITZELL, 1973)

- 1914 Stadi larvali di *Chauliodus Sloani* Bl. [Larval stages of *Chauliodus sloani* Bloch.] R[egio] Comitato Talassografico Italiano, Memoria **39**: 1–8, 1 pl.

SOII(5); LS(27); SZ(4) cited without reference code nor pagination; BCM; BMD.

The author of *C. sloani* is Schneider in Bloch *et al.*, 1801, but not Bloch. (MORROW, 1973a).

- 1915a Contributo alla conoscenza degli stadi larvali negli Scopelini Müller (*Bathophilus nigerrinus* Gigl., *Scopelus caninianus* C. e V., *Sc. Humboldti* Risso). [Contribution to the knowledge of larval stages in Scopelini Müller (*Bathophilus niger-rinus* Giglioli, *Scopelus caninianus* Cuvier et Valenciennes, *Scopelus humboldti* Risso).] Atti della R[eale] Accademia dei Lincei [5] Memoria **10 (17)**: 711–738, pls. 1–3.

SOIII(1); LS(28) [Publication date] 1914, which is the business year of the society; SZ not registered; CL [Text pagination] p. 714–720; BCM.

The Scopelini Müller is not accepted as a taxa in current nomenclature. According to LÜTKEN (1892: 287), referred by SANZO (1911: 252, footnote), the taxa was established for a family. It had been treated besides as any other category in the family-group by succeeding researchers. The author of *S. caninianus* is Valenciennes, 1849, in Cuv. Val.; *S. caninianus* and *S. humboldti* (= *Gasteropelecus humboldti* Risso, 1810) are together synonyms of *Myctophum punctatum* Rafinesque, 1810. (KREFFT and BEKKER, 1973)

- 1915b Contributo alla conoscenza dello sviluppo embrionale e post-embrionale degli Scopelini Müller (*Saurus griseus* Lowe, *Chlorophthalmus Agassizii* Bp, *Aulopus filamentosus* Cuv.) [Contribution to the knowledge of embryonic and post-embryonic development of Scopelini Müller (*Saurus griseus* Lowe, *Chlorophthalmus agassizii* Bonaparte, *Aulopus filamentosus* Cuvier).] Atti della R[eale] Accademia dei Lincei [5] Rendiconto **24 (1)**: 460–464.

LS (29) [Serial title] omitted; [Serial division] confused; SZ not cited; CL (Additional references) ; BCM. See Entry [1915f] on the same subject.

For the taxon Scopelini, see Entry [1915a]. The *Saurus griseus* Lowe, 1839, is a synonym of *Synodus saurus* (Linnaeus, 1758), and the author of *Aulopus filamentosus* is Cloquet, 1816, but not Cuvier. (NIELSEN, 1973a, b).

- 1915c Notizie ittologiche. I. Sulle cause determinanti l'approfondimento delle uova di Teleostei in sviluppo. [p. 131–132] II. Stadi larvali di *Stomias boa* Risso. [p. 132] III. Stadi larvali di *Bathophilus nigerrinus* Gigl. [p. 132] IV. *Stylophthalmoides Lobiancoi* e *St. mediterraneus* Mazzarelli sono rispettivamente le forme larvali di *Scopelus caninianus* e *Scopelus Humboldti* [= *Humboldti*]. [p. 133] V. Stadi larvali di *Chauliodus sloani* Bl. [p. 133] [Ichthyological news. I. On the causes determining the scrutiny of teleostean eggs in development. II. Larval stages of *Stomia boa* Risso. III. Larval stages of *Bathophilus nigerrinus* Giglioli. IV. *Stylophthalmoides lobiancoi* and *St. mediterraneus* Mazzarelli are respectively the larval forms of *Scopelus caninianus* and *Scopelus humboldti*. V. Larval stages of *Chauliodus sloani* Bloch.] Monitore Zoologico Italiano, Florence, **26 (5–6)**: 131–133.

SOI(18); LS(30) [Text title] modified with an annotation by the author; SZ not registered; CL [Text pagination] p. 131–144; BMD. This paper includes the five sections with their respective in-text subtitle, above. [Section 2] For the species name in the in-text subtitle, see Entry [1912b]. [Section 4] The nomenclature of the genus is referred later in the Section 4 of our article, below; the *S. lobiancoi* Mazzarelli, 1909, and *S. mediterraneus* Mazzarelli, 1909, are revised as *Myctophum punctum* Rafinesque, 1810, and *Symbolophorus veranyi* (Moreau, 1888) respectively; for the other two species, see Entry [1915a]. (KREFFT and BEKKER, 1973) See Entry [1915d] on the same subject. [Section 5] For the author of *C. sloani*, see Entry [1914a].

- 1915d *Stylophthalmoides Lobiancoi* Mazzarelli e *St. mediterraneus* Mazzarelli, sono le rispettive forme larvali di *Scopelus caninianus* C. V. e *Scopelus Humboldti* Risso. I. *Stylophthalmoides Lobiancoi*

- e forma larvale di *Scopelus caninianus* C. e V. [p. 3–11] II. *Stylophthalmooides mediterraneus* Mazzarelli e forma larvale dello *Sc. Humboldti* Risso. [p. 13–22] [*Styphthalmooides lobiancoi* Mazzarelli and *St. mediterraneus* Mazzarelli are respectively larval forms of *Scopelus caninianus* Cuvier et Valenciennes and *Scopelus humboldti* Risso. I. *Stylophthalmooides lobiancoi* is a larval form of *Scopelus caninianus* Cuvier et Valenciennes. II. *Stylophthalmooides mediterraneus* Mazzarelli is a larval form of *Scopelus humboldti* Risso.] R[egio] Comitato Talassografico Italiano, Memoria **44**: 1–26, 1 pl.
- SOII(6); LS(31); SZ(4) registered without reference code nor pagination; LIM; BMD. This paper includes two sections with their respective in-text subtitle, above.
- The genus *Stylophthalmooides* is not indexed in the Clofnam II. The type species (PAXTON, 1979; ESCHMEYER and BAILEY in ESCHMEYER, 1990) was subsequently designated as *Stylophthalmus lobiancoi* Mazzarelli, 1909, by Tåning, 1932. And this genus is revised (PAXTON, 1972) as a complex of synonyms of *Myctophum* Rafinesque, 1892, and *Symbolophorus* Bolin and Wisner, 1959. For the present synonym status of the two species in text title, see Entry [1915c], and for another taxonomic issue, see the Section 4, below, of our article.
- 1915e Stadi larvali di *Bathophilus nigerrimus* Gigl. [Larval stages of *Bathophilus nigerrimus* Giglioli.] R[egio] Comitato Talassografico Italiano, Memoria **48**: 1–11, 2 pls.
- SOII(7); LS(32); SZ(4) not coded; CL [Text pagination] p. 1–10; LIM; BMD.
- 1915f Contributo alla conoscenza dello sviluppo negli Scopelini Müller (*Saurus griseus* Lowe, *Chlorophthalmus Agassizii* Bp. ed *Aulopus filamentosus* Cuv.) I. Uova, stadi embrionali e post-embrionali di *Saurus griseus* Lowe. [p. 3–14] II. Stadi larvali di *Chlorophthalmus Agassizii* Bp. [p. 14–17] III. Stadi larvali di *Aulopus filamentosus* Cuv. [p. 17–19] [Contribution to the knowledge of development in Scopelini Müller (*Saurus griseus* Lowe, *Chlorophthalmus agassizii* Bonaparte and *Aulopus filamentosus* Cuvier). I. Eggs and embryonic and post-embryonic stages of *Saurus griseus* Lowe. II. Larval stages of *Chlorophthalmus agassizii* Bonaparte. III. Larval stages of *Aulopus filamentosus* Cuvier.] R[egio] Comitato Talassografico Italiano, Memoria **49**: 1–21, 3 figs., pls. 1–3.
- SOII(8); LS(33); SZ(4) without reference code nor pagination; LIM. This paper includes three sections with their respective in-text subtitle, above.
- For the taxon Scopelini, see Entry [1915a]. [Section 1] For the species name in the in-text subtitle, see Entry [1915b]. [Section 3] For the authorship of *A. filamentosus*, see Entry [1915b].
- 1917a Discorso inaugurale del Prof. Luigi Sanzo, Direttore dell'Istituto di Biologia Marina in Messina. [Inaugural address of Prof. Luigi Sanzo, Director of the Istituto di Biologia Marina in Messina.] R[egio] Comitato Talassografico Italiano, Bolletino Bimestrale **6** (39–44): 25–43.
- LS(34) [Publication date] 1916, [Text title] modified with an annotation by the author; SZ(3): BMD.
- 1917b Stadi larvali di *Paralepis hyalina* C. V. [Larval stages of *Paralepis hyalina* Cuvier et Valenciennes.] R[egio] Comitato Talassografico Italiano, Memoria **59**: 1–7, 1 pl.
- SOII(9); LS(35); SZ(6); CL; BCM; BMD.
- The *P. hyalina* Cuvier, 1829, in Cuvier and Valenciennes is a synonym of *Sudis hyalina* Rafinesque, 1810. (Post, 1973)
- 1917c Sviluppo larvali di *Paralepis Rissoi* Bp. [Larval development of *Paralepis rissoi* Bonaparte.] R[egio] Comitato Talassografico Italiano, Memoria **62**: 1–9.
- SOII(10); LS(36); SZ(6); CL [Text pagination] p. 3–9; BCM; BMD.
- The *P. rissoi* Bonaparte, 1840, is revised as *Notolepis rissoi* (Bonaparte). (Post, 1973)
- 1918a Stadi larvali di *P. sphyraenoides* Risso. [Larval stages of *Paralepis sphyraenoides* Risso.] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **27** (12): 450–454, figs. 1–2.
- SOI(22); LS(41); SZ not cited; CL [Authorship] SANZO, L.; GRASSI, B.; BCM. This paper is not a joint work with Grassi, who was the reader of this note presented by SANZO, as usual at the meeting of the day. Issues (semestre) of each volume are independently paginated each other.

The *Paralepis sphyrenoides* Risso, 1820, (= *P. sphyraenoides* of Cuvier, 1829) is revised as *Lestidiops sphyrenoides* (Risso). (Post, 1973)

- 1918b Nuovo contributo alla conoscenza dello sviluppo larvale di *Stomias boa* Risso. [New contribution to the knowledge of larval development of *Stomias boa* Risso.] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **27** (3): 77–82, figs. 1–2.

SOI(20); LS(39); SZ not registered; CL; BCM.

For the species name in the text title, see Entry [1912b].

- 1918c Sviluppo larvale di *Chauliodus Sloani* Bl. [Larval development of *Chauliodus sloani* Bloch.] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **27** (4): 91–97, figs. 1–4.

SOI(21); LS(40); SZ not registered; BCM.

For the species name in the text title, see Entry [1914].

- 1918d Nuovo contributo alla conoscenza dello sviluppo larvale di *Bathophilus nigerrimus* Gigl. [New contribution to the knowledge of larval development of *Bathophilus nigerrimus* Giglioli.] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **27** (11): 379–383.

SOI(19); LS(37); SZ not registered; CL; BCM.

- 1918e Stadi larvali di *Ichthyococcus ovatus* (Cocco). [Larval stages of *Ichthyococcus ovatus* (Cocco).] Atti della R[eale] Accademia dei Lincei [5] Rendiconti **27** (2): 413–415.

LS(38); SZ not registered; BCM.

For the species name in the text title, see Entry [1913a].

- 1918f Uova e larve di *Trachypterus cristatus* Bp. [Eggs and larvae of *Trachypterus cristatus* Bonaparte.] R[egio] Comitato Talassografico Italiano, Memoria **64**: 1–16, 1 pl.

SOII(11); LS(42); SZ(6); CL; BCM; BMD.

The author of the species is Bonelli, 1820, but not Bonaparte (Bp.); the *T. cristatus* Bonelli is revised as *Zu cristatus* (Bonelli). (PALMER, 1973b)

- 1918g Contributo alla conoscenza dello sviluppo post-embrionale negli Scopelini Müller. Nota I. *M. Gemellari* (Cocco). [p. 9–11] Nota II. [without subtitle, but on *M. Dofleini*] [p. 13–16] Nota III. *M. Rafinesquei* (Cocco). [p. 17–18] Nota IV. *M. Rissoi* (Cocco). [p. 19–21] Nota V. *M. Benoiti* (Cocco). [p. 23–25] Nota VI. *M. Benoiti Hygomi* (Lütken) A. Brauer. [p. 27–31] Nota VII. *M. glaciale* (Reinhardt). [p. 33] Nota VIII. *M. Coccoi* Cocco. [p. 35–37] Nota IX. *M. madarense* (Lowe). [p. 39–40] Nota X. *M. elongatum* (Costa). [p. 41–44] Nota XI. *M. alatum* (Goode e Bean). [p. 45–49] Nota XII. *M. crocodilum* (Risso). [p. 51–53] Nota XIII. *M. metopoclampum* (Cocco). [p. 55] [Contribution to the knowledge of post-embryonic development in Scopelini Müller. (with the in-text subtitles Notes I–XIII, as shown as above)] R[egio] Comitato Talassografico Italiano, Memoria **66**: 1–55.

SOII(12); LS(43–54) the Note 13 is omitted; SZ(7) the Note 7 is exclusively registered; CL; BCM; BMD. This paper includes 13 sections, or notes with their respective in-text subtitle, above.

For the taxon Scopelini, see Entry [1915a]. [Note 1] The *M. gemellari* of Bonaparte, 1840 (= *Nyctophus gemellarii* Cocco, 1838) is further revised as *Lobianchia gemellari* (Cocco). [Note 2] The *M. (Lampanyctus) dofleini* Zugmyer, 1811, is revised as *Lobianchia dofleini* (Zugmyer). [Note 3] The *M. rafinesquei* (= *Nyctophum rafinesquei* Cocco, 1838) is revised as *Diaphus rafinesquei* (Cocco). [Note 4] The *M. rissoi* of Täning, 1918 (= *Scopelus rissoi* Cocco, 1829) is revised as *Electrona rissoi* (Cocco). [Note 5] The *M. benoiti* (= *Scopelus benoiti* Cocco, 1838) is revised as *Hygophum benoiti* (Cocco). [Note 6] The *M. (M.) benoiti hygomi* of Brauer, 1906, is a synonym of *Hygophum hygomi* (Lütken, 1892). [Note 7] The *M. glaciale* (= *Scopelus glacialis* Reinhardt, 1837) is revised as *Benthosema glaciale* (Reinhardt). [Note 8] The *M. coccoi* (= *Scopelus coccoi* Cocco, 1829) is revised as *Gonichthys coccoi* (Cocco). [Note 9] The *M. madarense* (= *Scopelus madarensis* Lowe, 1839) is revised as *Ceratoscopelus madarensis* (Lowe). [Note 10] The *M. elongatum* (= *Scopelus elongatus* Costa, 1844) is revised as *Notoscopelus elongatus* (Costa). [Note 11] The *M. alatum* is a synonym of *Lampanyctus alatus* Goode et Bean, 1896. [Note 12] The *M. crocodilum* (= *Gasteropelecus crocodilus* Risso, 1810) is revised as

- Lampanyctus crocodilus* (Risso). [Note 13] The *M. metopoclampus* of Bonaparte, 1840, (= *Nyctophus metapoclampus* Cocco, 1829) is further revised as *Diaphus metopoclampus* (Cocco). (KREFFT and BEKKER, 1973)
- 1919 Contributo alla conoscenza degli stadi larvali di *Orthogoriscus* Bl. [Contribution to the knowledge of the larval stages of *Orthogoriscus* Bloch.] R[egio] Comitato Talassografico Italiano, Memoria **69**: 1-7, 1 pl.
SOII(13); LS(55) [Publication date] misprinted (1939); SZ(7); BCM; BMD.
The genus *Orthogoriscus* Schneider, 1801 (not Bloch) is a synonym of *Mola* Koelreuter, 1770. (TORTONESE, 1973c)
- 1921 Sulla biologia e pesca dei Pesce Spada. [On the biology and fishery of swordfish.] Rendiconto della dodicesima assemblea ordinaria e del convegno dell' Unione Zoologica Italiana in Trieste, 8-12 Settembre 1921. 1 p.
SOI(23); LS(56): SZ not registered. Pagination is not determined on the reprint issue.
- 1922 Uova e larve di *Xiphias gladius* L. [Eggs and larvae of *Xiphias gladius* Linnaeus.] R[egio] Comitato Talassografico Italiano, Memoria **79**: 1-18, pls. 1-2.
LS(57); SZ(4) registered without reference code nor pagination; CL [Pagination] 17 p., 2 pls.; BCM; BMD.
- 1924a Le presunte uova di Macruride sono uova di *Maurolicus hamethystinopunctatus* Cocco. [The presumed eggs of macrurids are those of *Maurolicus amethystinopunctatus* Cocco.] Atti della Società Italiana per il Progresso delle Scienze. Dodicesima Riunione. Catania, Aprile 1923. Parte II: 125-126.
LS(58) [Publication date] 1923; [Text title] modified (*Maurolicus Pennanti*); [Serial issue title] this publication is issued for the reunion in Catania, but not in Pavia; SZ not registered; BMD.
The *M. amethystinopunctatus* [not *hamethystinopunctatus*] Cocco, 1838, is a synonym of *M. meulleri* (Gmelin, 1789) (WITZELL, 1973).
- 1924b Uova e larve di *Argyropelecus Zemigymnus*. [Eggs and larvae of *Argyropelecus hemigymnus*.] Atti della Società Italiana per il Progresso delle Scienze. Dodicesima Riunione. Catania, Aprile 1923. Parte II: 126.
LS(59); SZ not registered; BMD. Original text title is misprinted (*Zemigymnus*).
- 1925a Uova e larve di Alalonga (*Orcynus germo* Ltkn.) [Eggs and larvae of albacore (*Orcynus germo* Lütken).] Atti della R[eale] Accademia Nazionale dei Lincei [6] Rendiconti **1** (3): 131-134.
SOI(24); LS(65); SZ(4); LIM; BCM.
Alalonga is a Sicilian name (PALOMBI and SANTARELLI, 1953) of the albacore.
- 1925b Uova e larve di *Regalecus glesne* Asc. [Eggs and larvae of *Regalecus glesne* Ascanius.] R[egio] Comitato Talassografico Italiano, Memoria **118**: 1-8, 1 pl.
SOII(14); LS(66); SZ not registered; CL [Text pagination] p. 1-7; BCM; BMD.
- 1926a Ricerche biologiche nella Crociera idrografica con la R. Nave Ammiraglio Magnaghi in Mar Rosso. [Biological researches during the hydrographic cruise by the R[oyal] Ship Ammiraglio Magnaghi in the Red Sea.] Atti della Società Italiana per il Progresso delle Scienze, XIV Riunione. Pavia, 24-29 Maggio 1925. p. 516-519.
LS(60); SZ not registered; BMD.
- 1926b Ricerche biologiche nella Crociera idrografica con la R. N. Ammiraglio Magnaghi in Mar Rosso. Uova e larve di Plectognati. [Biological researches during the hydrographic cruise by the R/S Ammiraglio Magnaghi in the Red Sea. Eggs and larvae of Plectognathi.] Atti della Società Italiana per il Progresso delle Scienze, XIV Riunione. Pavia, 24-29 Maggio 1925. p. 519.
LS(61); SZ not registered; BMD.
- 1926c Ricerche biologiche nella Crociera idrografica con la R. N. Ammiraglio Magnaghi in Mar Rosso. Uova e larve di *Echeneis naucrates*. [Biological researches during the hydrographic cruise by the R/S Ammiraglio Magnaghi in the Red Sea. Eggs and larvae of *Echeneis naucrates*.] Atti della Società Italiana per il Progresso delle Scienze. XIV Riunione. Pavia, 24- 29

Maggio 1925. p. 519–520.

LS(62); SZ not registered; BMD.

- 1926d Ricerche biologiche nella Crociera idrografica con la R. N. Ammiraglio Magnaghi in Mar Rosso. Uova e larve di *Regalecus gladius* Walb. [Biological researches during the hydrographic cruise by the R/S Ammiraglio Magnaghi in the Red Sea. Eggs and larvae of *Regalecus gladius* Walbaum.] Atti della Società Italiana per il Progresso delle Scienze. XIV Riunione. Pavia, 24–29 Maggio 1925. p. 520–521.

LS(63); SZ not registered, BMD.

The species name in the text title is not easily identified. It may be confused with two species: *Regalecus remipes* of Walbaum, 1792, and *Gymnetrus gladius* Valenciennes, 1835, in Cuv. Val. They are the synonym of *Regalecus glesne* Ascarius, 1772. (PALMER, 1973a) This name is applied in the SPARTÀ's list (Entry No. 63, above), where the original title is rearranged.

- 1926e Ricerche biologiche nella crociera idrografica con la R. N. Ammiraglio Magnaghi in Mar Rosso. Nuovo probabile uovo di Anguilla. [Biological researches during the hydrographic cruise by the R/S Ammiraglio Magnaghi in the Red Sea. Probably new record of an eel egg.] Atti della Società Italiana per il Progresso delle Scienze. XIV Riunione. Pavia, 24–29 Maggio 1925. p. 521.

LS(64); SZ not registered; BMD.

- 1927a Uova e larve di *Echeneis naucrates* (Linn.) Nota preliminare. [Eggs and larvae of *Echeneis naucrates* (Linnaeus). Preliminary note.] R[egio] Comitato Talassografico Italiano, Memoria **133**: 1–5.

SOII(15); LS(69); SZ(5) [Serial number] misread (83); CL [Serial number] misprinted (130); [Text pagination] p. 3–5; BCM; BMD.

The *E. naucrates* Linnaeus, 1758, is a valid species name, but not a revised one. (LACHNER, 1973)

- 1927b Per un maggiore rendimento della Pesca e dell'Industria peschereccia in Italia. I. Reazione negativa del tonno alla luce e suo sfruttamento a beneficio delle nostre tonnare. [For a larger fishery and fisheries industries productivity in Italy. I. Negative reaction of bluefin tuna to the light and its exploitation for the benefit of our tuna-fishing fixed net.] R[egio] Comitato Talassografico Italiano, Memoria 134: 1–11.

LS(68) [Serial issue number] misprinted (CXXIVX); SZ(5) [Serial issue number] misread (84); BCM; BMD.

- 1927c *Xiphias gladius* L. [*Xiphias gladius* Linnaeus.] in Faune et flore de la Méditerranée, Fasc. 7. Paris: Institut Océanographique. 2 p., figs. 1–7.

LS not cited; SZ(5); BCM. This book was published in 1927–1935 on a slip system without pagination; see GERMAIN (1935) for further detail of bibliography.

- 1927d Contributo alla conoscenza di uova e larve di Plectognati. Nota preliminare. [Contribution to the knowledge of eggs and larvae of Plectognathi. Preliminary note.] Bollettino dell'Istituto di Zoologia, Reale Università di Roma, **5**: 123–128.

LS not cited; SZ(5) [Text pagination] 6 p.; BCM; LIM

- 1928a Nuovo tipo di rete planctonica ad apertura e chiusura a momenti voluti. [New model of plankton net for opening and closing at desired moments.] Bollettino della Società Italiana di Biologia Sperimentale **2** (7).

LS(70); SZ not registered. Pagination of this paper is not yet determined. See Entry [1928g] on the same subject.

- 1928b Variazioni di peso specifico di una massa gelatinosa galleggiante di uova di Teleostei. [Variations in specific gravity of a floating gelatinous mass of teleostean eggs.] Bollettino della Società Italiana di Biologia Sperimentale **3** (3): 261–264.

SOI(25); LS(71); SZ(6). See Entry [1029e] on the same subject.

- 1928c Uova, sviluppo embrionale, stadi larvali, post-larvali e giovanili di Sternoptychidae e Stomiidae. Sternoptychidae. I. *Argyropelecus hemigymnus* Cocco. [Eggs, embryonic develop-

- ment, larval, post-larval and juvenile stages of Sternoptychidae and Stomiatidae. Sternoptychidae. I. *Argyropelecus hemigymnus* Cocco.] R[egio] Comitato Talassografico Italiano, Seconda Monografia (1928): 1-83 [including 14p. of plate legend and 1 page of errata], figs. 1-11, pls. 1-7.
 SOIII(8); LS(84); SZ(10) [Pagination] p. 5-68, pls. 1-8; CL [Text pagination] p. 1-68. The series of works starts from the subseries "Sternoptychidae," which was continued to the third paper, Entry [1935], and the subseries "Stomiatidae" was not realized in the series concerned.
- 1928d Uova e larve di *Remora remora* L. [Eggs and larvae of *Remora remora* Linnaeus.] R[egio] Comitato Talassografico Italiano, Memoria **138**: 1-11, 1 pl.
 SOII(16); LS(72); SZ(5); CL [Text pagination] p. 3-11; BCM; BMD.
 The species name shown in the text title is a revised name of *Echeneis remora* Linnaeus, 1758, after Gill, 1863. (LACHNER, 1973)
- 1928e Uova e larve di *Zeus Faber* L. Nota preliminare. [Eggs and larvae of *Zeus faber* Linnaeus. Preliminary note.] R[egio] Comitato Talassografico Italiano, Memoria **139**: 1-4.
 SOII(17); LS(73); SZ(6); BCM; BMD.
- 1928f Contributo alla conoscenza di uova e larve di "*Brama Raji*" Bl. [Contribution to the knowledge of eggs and larvae of *Brama raji* Bloch.] R[egio] Comitato Talassografico Italiano, Memoria **147**: 1-10, 1 pl.
 SOII(18); LS(74); SZ(7) [Text pagination] 8 p.; BCM; BMD.
 The *B. raji* of Bloch and Schneider, 1801, [not of Bloch] (= *Sparus raji* Bloch, 1791) is a synonym of *Brama brama* (Bonnatere, 1788). (MEAD, 1973)
- 1928g Nuovo tipo di rete planktonica in serie ad apertura e chiusura a momenti voluti. [New model of plankton net for sequential collecting by opening and closing at desired moments.] R[egio] Comitato Talassografico Italiano, Memoria **148**: 1-18, pls. 1-3.
 LS(75); SZ not registered; BCM; BMD. See Entry [1928a] on the same subject.
- 1929a Biologia e pesca del Pesce Spada (*Xiphias gladius* L.) [Biology and fishery of swordfish (*Xiphias gladius* Linnaeus).] Atti del Convegno di Biologia Marina Applicata alla Pesca. Messina, Giugno 1928. p. 1-8.
 SOI(26); LS(76) [Publication date] 1928; SZ(8).
- 1929b Biologia dell'anguilla. [Biology of the eel.] Atti del Convegno di Biologia Marina Applicata alla Pesca. Messina, Giugno 1928.
 LS(77); SZ(7) [Text pagination] 16 p.
- 1929c Uova e larve di Tonno ("*Orcynus thynnus* Ltkn.") [Eggs and larvae of bluefin tuna (*Orcynus thynnus* Lütken).] Atti della R [eale] Accademia Nazionale dei Lincei [6] Rendiconti **9** (1): 104-106.
 SOI(27); LS(79); SZ(7); CL; BCM.
 For the species name in the text title, see Entry [1910a].
- 1929d Contributo alla conoscenza delle produzioni scheletriche cutanee nei Teleostei. [Contribution to the knowledge of the cutaneous skeleton production in teleosteans.] Atti del IV Congresso Internazionale di Limnologia Teorica ed Applicata. [Roma, 1929.] p. 547-552.
 SOI(28); LS(80); SZ(8).
- 1929e Peso specifico e sue variazioni in uova galleggianti di Teleostei. I°. Uova racchiuse in massa gelatinosa. [Specific gravity and its variations in teleostean floating eggs. I. Eggs contained in gelatinous mass.] R[egio] Comitato Talassografico Italiano, Memoria **150**: 1-14, figs. 1-2.
 SOII(19); LS(81); SZ(7); BCM; BMD. See Entry [1928b] on the same subject.
- 1929f Nidamento pelagico, uova e larve di "*Thysanoteuthis rhombus*" Troschel. [Pelagic nest materials, eggs and larvae of *Thysanoteuthis rhombus* Troschel.] R[egio] Comitato Talassografico Italiano, Memoria **161**: 1-10, 1 pl.
 SOII(20); LS(82) [Serial issue number] misprinted (CXI); SZ(8) [Text pagination] 9 p.; BCM; BMD.

- 1930a Campagna idrografica nel Mar Rosso della Regia Nave Ammiraglio Magnaghi 1923–24. Ricerche biologiche su materiali raccolti dal Prof. L. Sanzo: Memoria I. Itinerario e stazione biologiche della crociera. Relazione del Prof. Luigi Sanzo. I. Introduzione. [p. 119] II. Itinerario della crociera e stazioni biologiche compiute. [p. 121–127, fig. 1] III. Obbiettivi principali delle ricerche biologiche compiute. [p. 129–139, fig. 2] IV. Quadro di ritrovo delle stazioni biologiche delle annesse tavole IV–V–VI–VII. [p. 141] V. Tabelle dei dati di pesca per le singole stazioni biologiche. [p. 143–164] [Hydrographic cruise in the Red Sea of the Royal Ship Ammiraglio Magnaghi 1923–24. Biological researches on material collected by Prof. L. Sanzo: Memoir I. Itinerary and biological stations of the cruise. Report by Prof. Luigi Sanzo. I. Introduction. II. Itinerary of the cruise and biological stations accomplished. III. Principal objectives of the biological researches accomplished. IV. Summary of the biological stations in the annex tables 4–7. V. Lists of catch data by biological station.] Istituto Idrografico della Regia Marina, Annali Idrografici **11bis**: 117–164, fig. 1, pls. 1–7.
SOIII(2) [Publication date] 1928; LS(78); SZ(6) [Publication date] 1928; [Pagination] 48 p., 2 figs, 4 pls.; BII. This paper includes the five sections with their respective in-text subtitle, above.
- 1930b Campagna idrografica nel Mar Rosso della Regia Nave Ammiraglio Magnaghi 1923–24. Ricerche biologiche su materiali raccolti dal Prof. L. Sanzo: Memoria IV. Contributo alla conoscenza di uova, larve e stadi giovanili in *Echeneis naucrates* Linn. [Hydrographic cruise in the Red Sea by the Royal Ship Ammiraglio Magnaghi 1923–24. Biological researches on material collected by Prof. L. Sanzo: Memoir IV. Contribution to the knowledge of eggs, larvae and juvenile stages in *Echeneis naucrates* Linnaeus.] Istituto Idrografico della Regia Marina, Annali Idrografici **11bis**: 201–211, 1 fig., 1 pl.
LS(67); SZ(5) [Publication date] 1927; [Text pagination] 9 p.; CL; BCM; BII.
- 1930c Campagna idrografica nel Mar Rosso della Regia Nave Ammiraglio Magnaghi 1923–24. Ricerche biologiche su materiali raccolti dal Prof. L. Sanzo: Memoria VII. Plectognati. [Hydrographic cruise in the Red Sea by the Royal Ship Ammiraglio Magnaghi 1923–24. Biological researches on material collected by Prof. L. Sanzo: Memoir VII. Plectognathi.] Istituto Idrografico della Regia Marina, Annali Idrografici **11bis**: 375–459, + 14 p., figs. 1–21, 8 pls. [including one title page of the plates] .
SOIII(2) [Publication date] 1929; LS not listed; SZ(8) [Publication date] 1929; [Text pagination] 95 p.
- 1930d Ricerche biologiche su materiali raccolti dal Prof. L. Sanzo nella Campagna idrografica nel Mar Rosso della R. N. Ammiraglio Magnaghi 1923–1924. “Plectognati”. [Biological research on material collected by Prof. L. Sanzo during the hydrographic cruise in the Red Sea of the R/S Ammiraglio Magnaghi 1923–1924. Plectognathi.] R[egio] Comitato Talassografico Italiano, Memoria **167**: 1–126, pls. 1–7.
LS(83) [Publication date] 1929; [Text title] apparently confused with Entry [1930c]; [Serial issue number] misprinted (CLXXVII); SZ not registered; BCM; BMD.
- 1930e Giovanissimo stadio larvale di *Xiphias gladius* L. di mm 6,4. [Earliest larval stage of *Xiphias gladius* Linnaeus, 6.4 mm long.] R[egio] Comitato Talassografico Italiano, Memoria **170**: 1–9, 1 pl.
LS not cited; SZ(9) [Text pagination] 8 p.; CL [Pagination] 8 p., 3 figs. (the 3 figures are drawn on the plate mentioned above); BCM; BMD. See Entry [1930i] on the same subject.
- 1930f Uova e larve di *Mugil cephalus* Cuv. ottenute per fecondazione artificiale (Nota Preventiva). [Eggs and larvae of *Mugil cephalus* Cuvier, obtained by artificial fecondation (Preventive Note).] R[egio] Comitato Talassografico Italiano, Memoria **179**: 1–5.
SOII(21); LS(85) [Serial issue number] misprinted (CXXIX); SZ(9) ; BCM; BMD.
The authorship of *M. cephalus* is Linnaeus, 1758, but not Cuvier, 1817 (part.) or 1829, and the species is revised as *M. cephalus cephalus* (Linnaeus). (TREWAVAS, 1973)
- 1930g Uova, sviluppo embrionale, stadi larvali, post-larvali e giovanili di Sternoptychidae e

- Stomiidae. Sternoptychidae. 2. *Ichthyococcus ovatus* Cocco. [Eggs, embryonic development and larval, post-larval and juvenile stages of Sternoptychidae and Stomiidae. Sternoptychidae. 2. *Ichthyococcus ovatus* Cocco.] R[egio] Comitato Talassografico Italiano, Seconda Monografia (1930): 69–119, fig. 12, pls. 8–9.
 SOIII(9); LS(90); SZ(9) [Publication date] 1931; [Text pagination] p. 73–114; CL [Text pagination] p. 71–119. See an annotation in Entry [1928c] on the series title.
- 1930h Attività scientifica dell'Istituto Centrale di Biologia marina in Messina. in Relazione sull'attività del R. Comitato Talassografico nell'esercizio 1928–29. [Scientific activities of the Istituto Centrale di Biologia Marina in Messina. in Report on the activity of the Regio Comitato Talassografico in the execution 1928–1929.] Bollettino del Consiglio Nazionale delle Ricerche **19**: 10–15.
 SOI(29); LS(86) [Serial issue number] not cited; SZ not registered
- 1930i Giovanissima larva di *Xiphias gladius* L., lunga mm 6,40. [Earliest larva of *Xiphias gladius* Linnaeus, 6.40 mm long.] Bollettino di Zoologia, Napoli, **1** (1): 31.
 SOI(30); LS(87); SZ not registered; BCM. See Entry [1930e] on the same subject.
- 1930j Contributo alla conoscenza dello sviluppo nei Carancidi—*Seriola Dumerilii* Risso. [Contribution to the knowledge of development in Carangidae. *Seriola dumerilii* Risso.] Bollettino di Zoologia, Naples, **1** (1): 33–34.
 SOI(31); LS(88); SZ(8); CL; BCM.
 The Carancidi in the text title is read as Carangidi (PALOMBI and SANTARELLI, 1953); the *S. dumerilii* (= *Caranx dumerili* Risso, 1810) is revised as *S. dumerili* (Risso). (HUREAU and TORTONESE, 1973)
- 1930k Peso specifico in uova di *Exocoetus* e portata biologica dei filamenti di attacco di esse uova e corpi solidi galleggianti. [Specific gravity in eggs of the *Exocoetus*, and biological importance of the binding filaments of its eggs and floating solid bodies.] Bollettino della Società Italiana di Biologia Sperimentale **5** (6): 1–2.
 SOI(32) [Text title] misprinted (EVOCOETUS); LS(89); SZ(8).
- 1931a Uova, stadi embrionali e post-embrionali di *Naucrates ductor* L. [Eggs and embryonic and post-embryonic stages of *Naucrates ductor* Linnaeus.] R[egio] Comitato Talassografico Italiano, Memoria **185**: 1–16, 1 pl.
 SOII(22); LS(91); SZ(9); CL [Text pagination] p. 1–14; BCM; BMD.
 The originally designated name of this species is *Gasterosteus ductor* Linnaeus, 1758, which was revised as *Naucrates ductor* (Linnaeus) after Cuvier, 1832. (HUREAU and TORTONESE, 1973)
- 1931b Azione dell'acqua marina sulla fermentazione alcoolica. [Action of seawater on alcoholic fermentation.] Atti della R[eale] Accademia Nazionale dei Lincei [6] Rendiconti **13** (2): 140–143.
 LS(99); SZ(S & P); BCM. This article is a joint work as the senior author with F. PIRRONE.
- 1931c Acqua di mare irradiata con raggi ultravioletti e sua azione sulla velocità della fermentazione alcoolica di soluzioni di glucosio. [Seawater irradiated with ultraviolet rays and its action on the velocity of the alcoholic fermentation of glucose solutions.] Atti della R[eale] Accademia Nazionale dei Lincei [6] Rendiconti **13** (8): 613–617.
 LS(98); SZ(S & P); BCM. This article is a joint work as the senior author with F. PIRRONE.
- 1931d Uova e primi stadi larvali di «*Myctophum Gemellari*» Cocco (= «*Scopelus Gemellari*» C. e V.). [Eggs and early larval stages of *Myctophum gemellari* Cocco (= *Scopelus gemellari* Cuvier et Valenciennes).] Atti della R[eale] Accademia Nazionale dei Lincei, [6] Rendiconti **14** (2): 515–519, figs. 1–3.
 SOI(34); LS(94); SZ not registered; BCM.
 The *S. gemellari* of Valenciennes, 1849, in Cuv. Val. is a junior synonym of *M. gemellari* of Bonaparte, 1840. For further details, see the annotation on Entry [1918g (Note I)]
- 1931e Sottordine: Salmonoidei. in Uova, larve e stadi giovanili di Teleostei. Monografia elaborata con l'uso del materiale raccolto e seriato da Salvatore Lo Bianco. [Suborder: Salmonoidei. in

Eggs, larvae and juvenile stages of Teleostei. Monographs elaborated by the use of the material collected and seriated by Salvatore Lo Bianco.] *Fauna e flora del Golfo di Napoli*, Monografia **38** (1931): 21–42, figs. 24–32, pls. 2–3 [with 4 pages of plate legend].

SOIII(5); LS(92); SZ not registered (but deposited in the Library of the Station); CL [Pagination] p. 21–92, figs. 31–58, pls. 2–7; LIM. The works in this and the next entry are published independently each other. This Monographs were reprinted as a book in two parts in 1956 by the Stazione Zoologica Anton Dohrn Napoli with the aid of the UNESCO. For this monograph, an English edition (Code No. TT68–50356) was published in 1969 by the Israel Program for Scientific Translation.

- 1931f Sottordine: Stomiatoidei. in Uova, larve e stadi giovanili di Teleostei. Monografia elaborata con l'uso del materiale raccolto e seriato da Salvatore Lo Bianco. [Suborder: Stomiatoidei. in Eggs, larvae and juvenile stages of Teleostei. Monographs elaborated by the use of the material collected and seriated by Salvatore Lo Bianco.] *Fauna e flora del Golfo di Napoli*, Monografia **38** (1931): 42–92, figs. 33–58, pls. 4–7 [with 8 pages of plate legend].

SOIII(5); LS(92); SZ not registered. See also an annotation for Entry [1931e].

- 1931g Si riproduce l'«*Anguilla vulgaris*» nel Mediterraneo? [Does *Anguilla vulgaris* reproduce itself in the Mediterranean?] VIIème Congrès International d'Aquaculture et de Pêche. Paris. 1931. 8 p.

SOI(33); LS(93); SZ not registered; LIM. This paper is included in: Rapports sur les questions mises à l'ordre du jour par la Commission Internationale d'Organisation du Congrès. Groupe II. Pêches fluviales. Section N° 1. Etude scientifique des eaux douces. Question No 18. Anguille. Reprint issue, SOI(33), shows "Groupe I," being misprinted for Groupe II, above.

The *A. vulgaris* Shaw, 1803, is a subjective synonym of *Muraena anguilla* Linnaeus, 1758, and revised as *Anguilla anguilla* (Linnaeus). (BLACHE, BAUCHOT and SALDANHA, 1973a)

- 1931h Nuovo metodo di colorazione della cartilagine impiegato nello studio della composizione scheletrica del cranio nei Teleostei, [New method of the cartilage coloration used in the skeletal composition study of the teleostean cranium.] *Bollettino della Società Italiana di Biologia Sperimentale* **6** (4): 1–2.

SOI (35); LS(95); SZ(9) [Text pagination] 2 p.

- 1931i Uova e larve di *Zeus faber* L. [Eggs and larvae of *Zeus faber* Linnaeus.] *Archivio Zoologico Italiano*, Naples, **15**: 475–483, pl. 5.

SOI(36); LS(96); SZ(10).

- 1932a Nuovo contributo alla conoscenza delle uova e primi stadi larvali negli Scomberoidi. [New contribution to the knowledge of eggs and early larval stages in Scombroidei.] *Bollettino di Zoologia*, Naples, **3** (1–2): 69–72.

SOI(37); LS(100); SZ not registered; CL [Publication date] 1931; BCM.

For the suborder name in the text title, see Entry [1909b, 1910b, d] on a similar subject.

- 1932b Uova e primi stadi larvali di *Tracurus mediterraneus*. [Eggs and early larval stages of *Trachurus mediterraneus*.] *Bollettino di Zoologia*, Napoli, **3** (1–2): 73.

SOI(39) [Text title] misprinted (*Tracurus*); LS(102) [Text title] misprinted (...stadi di...); SZ not registered; CL; BCM.

The *T. mediterraneus* of Lütken, 1880 (= *Caranx trachurus* var. *mediterraneus* Steindachner, 1869) is revised as *T. mediterraneus mediterraneus* (Steindachner). (HUREAU and TORTONESE, 1973)

- 1932c Uova e primi stadi larvali di Mugilidi. [Eggs and early larval stages of Mugilidae.] *Bollettino di Zoologia*, Naples, **3** (1–2): 75–77.

SOI(40); LS(103); SZ not registered; BCM.

- 1932d Uova e larve di *Gonostoma denudatum* Raf. [Eggs and larvae of *Gonostoma denudatum* Rafinesque.] *Bollettino di Zoologia*, Naples, **3** (1–2): 79–80.

SOI(38); LS(101); SZ not registered; BCM.

- 1932e Uova e primi stadi larvali di *Pelamys sarda* C. V. [Eggs and early larval stages of *Pelamys sarda* Cuvier et Valenciennes.] R[egio] Comitato Talassografico Italiano, Memoria **188**: 1–10, 1 pl.
 SOII(23); LS(97) [Publication date] misprinted (1931); [Text title] misprinted (*Pelamis*); SZ not registered; CL (Suppl '78) [Text pagination] p. 1–9; BCM; BMD.
 For the species name in the text title, see Entry [1910b]. The genus *Pelamis* (Plumier) Lacepède, 1802, non valid, is a synonym of the Crangid genus *Oligoplites* Gill, 1863. (JORDAN, 1963; GOLVAN, 1965)
- 1932f Uova e primi stadi larvali di Tonno (*Orcynus thynnus* Ltkn.) [Eggs and early larval stages of bluefin tuna (*Orcynus thynnus* Lütken).] R[egio] Comitato Talassografico Italiano, Memoria **189**: 1–16, 1 pl.
 SOII(24); LS(104); SZ not registered; BCM; BMD.
 For the species name in the text title, see Entry [1910a].
- 1932g Uova, stadi larvali e giovanili di *Centrolophus Pompilus* C. V. [Eggs and larval and juvenile stages of *Centrolophus pompilus* Cuvier et Valenciennes.] R[egio] Comitato Talassografico Italiano, Memoria **196**: 1–16, 1 pl.
 SOII(25); LS(105); SZ not registered; CL [Illustration] 12 figs.; BCM; BMD. The plate includes 12 figures.
 The *C. pompilus* Cuvier, 1833, in Cuvier and Valenciennes is a synonym of *Centrolophus niger* (Gmelin, 1789). (HAEDRICH, 1973)
- 1932h Famiglia 2: Macruridae. in Uova, larve e stadi giovanili di Teleostei... [Family 2: Macrouridae. in Eggs, larvae and juvenile stages of Teleostei...] Fauna e flora del Golfo di Napoli, Monografia **38** (1932): 255–263, figs. 227–230, pl. 16 with 2 pages of plate legend.
 SOIII(6); LS(113); SZ not registered; CL [Publication date] 1933; LIM. For the full text title and a related bibliographic annotation, see Entry [1931f].
 The type genus is *Macrourus* Bloch, 1786, which has often been spelled as *Macrurus*. In this paper are referred the following 3 species (SPARTÀ, 1941): (i) *Hymenocephalus italicus* Giglioli, 1884; (ii) *Macrourus coelorhynchus* of Bonaparte, 1831–1841 (= *Lepidoleprus coelorhynchus* Risso, 1910), that is revised as *Coelorhynchus coelorhynchus* (Risso); (iii) *Macrourus sclerorhynchus* Valenciennes, 1838, in Webb and Berthelot, 1837–1844, that is revised as *Nezumia sclerorhynchus* (Valenciennes). (MARSHALL, 1973)
- 1933a Uova e primi stadi larvali di Alalonga (*Orcynus germo* Ltkn.) [Eggs and early larval stages of albacore (*Orcynus germo* Lütken).] R[egio] Comitato Talassografico Italiano, Memoria **198**: 1–10, 1 pl.
 SOII(26); LS(106); SZ not registered; BCM; BMD.
 For the species name in the text title, see Entry [1910b (Section III)].
- 1933b Uova, larve e stadi giovanili di *Seriola Dumerilii* Risso. [Eggs, larvae and juvenile stages of *Seriola dumerilii* Risso.] R[egio] Comitato Talassografico Italiano, Memoria **205**: 1–14, 1 pl.
 SOII(27); LS(107); SZ not registered; CL [Text pagination] p. 1–12; BCM; BMD.
 For the species name in the text title, see Entry [1930j].
- 1934 Uova, stadi larvali e giovanili di *Dactylopterus volitans* L. [Eggs, larval and juvenile stages of *Dactylopterus volitans* Linnaeus.] R[egio] Comitato Talassografico Italiano, Memoria **207**: 1–26, 1 pl.
 SOII(28); LS(109) [Publication date] 1933; SZ not registered; CL [Publication date] 1933; [Ex-text elements] 1 pl. n. num., 22 figs.; BCM; BMD. The plate includes 22 figures.
 The *D. volitans* of Swainson, 1839 (= *Trigla volitans* Linnaeus, 1758) is revised as *Cephalacanthus volitans* (Linnaeus). (MONOD, 1973)
- 1935 Uova, sviluppo embrionale, stadi larvali, post-larvali e giovanili di Sternoptychidae e Stomiatidae. Sternoptychidae. 3. *Maurolicus pennanti* (Walb.) [Eggs, embryonic development and larval, post-larval and juvenile stages of Sternoptychidae and Stomiatidae. Sternoptychidae.

chidae. 3. *Maurolicus pennanti* (Walbaum).] R[egio] Comitato Talassografico Italiano, Seconda Monografia (1935): 121–181, figs. 13–16, pls. 10–12.

SOIII(10); LS(111) [Publication date] 1933; SZ(10) [Text pagination] p. 123–181; CL [Text pagination] p. 123–180. For the series title of this work, see the annotation of Entry [1928c].

The author of *M. pennanti* is Day, 1880–1884, which was not cited by Walbaum. (WITZELL, 1973).

For this species name, see also Entry [1923a]

1936a Le uova dei Teleostei marini (Considerazioni generali). [The eggs of marine teleosteans (General considerations).] Atti della Società Italiana per il Progresso delle Scienze 4: 1–16.

SOI(42); LS(112); SZ not registered; BMD. On p. 2 (back of the title page) of the reprint, SOI(42), the following description is given: Relazione presentate in occasione alla XXIV Riunione della S. I. P. S., Palermo, 12–18 ottobre 1935–XIII [XIV], ed estratta dagli "Atti" della Società (Vol. 4°).

1936b Allevamento di una larva pelagica di «*Cerianthus*» fino all'acquisto di caratteri definitivi. Nota preliminare. [Culture of a pelagic larva of the *Cerianthus* up to the acquisition of definitive characters. Preliminary note.] Atti della R[eale] Accademia Nazionale dei Lincei [6] Rendiconti 24 (7–8): 227–231, figs. 1–3.

SOI(43); LS not enlisted; SZ(10); BCM.

1936c Contributi alla conoscenza dello sviluppo embrionario e post-embrionario nei Mugilidi. I. Uova e larve di *Mugil cephalus* Cuv. ottenute per fecondazione artificiale. [p. 3–6] II. Uova e larve di *Mugil chelo* Cuv. [p. 7–11] [Contributions to the knowledge of the embryonic and post-embryonic development in mugilids. I. Eggs and larvae of *Mugil cephalus* Cuvier obtained by artificial fecondation. II. Eggs and larvae of *Mugil chelo* Cuvier.] R[eale] Comitato Talassografico Italiano, Memoria 230: 1–14, pls. 1–2.

LS(110) [Publication date and serial issue title] not cited; SZ(10) [Text pagination] 12 p.; CL [Text pagination] 11 p.; BCM; BMD. This paper includes 2 sections with their respective in-text subtitle, above.

For the nomenclature of *M. cephalus*, see Entry [1930f]; the *M. chelo* Cuvier, 1829, is a synonym of *Chelon labrosus* (Risso, 1826). (TREWAVAS, 1973)

1937a Colonia pelagica di uova di Chetognati (*Spadella draco* Krohn). [Pelagic egg colony of a chaetognath (*Spadella draco* Krohn).] R[egio] Comitato Talassografico Italiano, Memoria 239: 1–8, 1 pl.

SOII(30); LS(114); SZ(10) [Text pagination] 7 p.; BCM; BMD.

1937b Uova e larve di *Mugil labeo* Cuv. [Eggs and larvae of *Mugil labeo* Cuvier.] Bollettino di Pesca, di Piscicoltura e di Idrobiologia, Rome, 13 (5): 506–510.

SOI(44) [Pagination] p. 1–7, including a title page sheet; LS(115); SZ not registered; CL; BCM.

See also Entry [1938a] on the same subject.

The *M. labeo* Cuvier, 1829, is revised as *Oedalechilus labeo* (Cuvier). (TREWAVAS, 1973)

1938a Uova e larve di *Mugil labeo* Cuv. [Eggs and larvae of *Mugil labeo* Cuvier.] Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée, Rapports et Procès-Verbaux des Réunions 11 [n. s.]: 73–76.

SOI(41); LS(108) [Publication date] not given; SZ not registered; CL; LIM.

For the species name in the text title, see Entry [1937b].

1938b Uova, stadi embrionali, prelarve e larve di *Saurenhelys cancrivora* Peters. [Eggs, embryonic stages, prelarvae and larvae of *Saurenhelys cancrivora* Peters.] R[egio] Comitato Talassografico Italiano, Memoria 249: 1–12, 1 pl.

SOII(31); LS(116) [Serial issue number] misprinted (CCLXXX); SZ not registered; CL [Pagination] 10 p., 12 figs.; BCM; BMD. The plate includes 12 figures.

1938c Uova ovariche mature e sviluppo larvale di *Aulopus filamentosus* Cuv. [Ripe ovarian eggs and larval development of *Aulopus filamentosus* Cuvier.] R[egio] Comitato Talassografico Italiano, Memoria 254: 1–8, 1 pl.

- SOII(32); LS(117) [Serial issue number] not given; SZ not registered; BCM; BMD.
For the species name in the text title, see Entry [1915b].
- 1939a Uova e larve di *Smaris insidiator* C. V. [Eggs and larvae of *Smaris insidiator* Cuvier et Valenciennes.] R[egio] Comitato Talassografico Italiano, Memoria **262**: 1–10, 1 pl.
SOII(33); LS(118); SZ not registered; CL [Text pagination] p. 1–8; BCM; BMD.
The *S. insidiator* Valenciennes, 1830, in Cuv. Val. is a synonym of *Centracanthus cirrus* Rafinesque, 1810. (TORTONESE, SERTORIO and BAUCHOT, 1973)
- 1939b Osservazioni biologiche sullo sviluppo di una larva pelagica di *Cerianthus*, potuta allevare fino all'acquisto dei caratteri definitivi e sul destino dei tentacoli isolati dal corpo. [Biological observations on the development of a pelagic larva of *Cerianthus*, which can be cultured up to the acquisition of definitive characters, and on the destiny of the tentacles isolated from the body.] R[egio] Comitato Talassografico Italiano, Memoria **266**: 1–12, 1 pl.
SOII(34); LS(119) [Serial issue number] misprinted (LCC); SZ not registered; BMD.
- 1939c Nuovo contributo alla conoscenza dello sviluppo di *Myctophum Rissoi* (Cocco). [New contribution to the knowledge of the development of *Myctophum rissoi* (Cocco).] Atti della Accademia Gioenia di Scienze Naturali in Catania [6] 3, Memoria **25**: 1–8, 1 pl.
SOIII(4); LS(120); SZ not registered; BCM. The "Memoria" number is simply the code number for papers in the issue, but the pagination is made by Memoria.
For the species name in the text title, see Entry [1918g (Note IV)].
- 1939d Rarissimi stadi larvali di Teleostei (*Lophotes cepedianus* Giorna; ...; *Balistes capriscus* L.) Nota I. *Lophotes cepedianus* Giorna. [p. 121–129] Nota II. *Eretmophorus Kleinbergi* Gigl. [p. 131–134] Nota III. *Ichthyococcus ovatus* Cocco. [p. 135–137] Nota IV. *Dactylopterus vo[l]itans* L. [p. 139–142] Nota V. *Orthogoriscus mola* Linn. [p. 143–146] Nota VI. *Balistes capriscus* L. [p. 147–149] [Very rare larval stages of teleosteans (...)] Note I. *Lophotes cepedianus* Giorna. Note II. *Eretmophorus kleinbergi* Giglioli. Note III. *Ichthyococcus ovatus* Cocco. Note IV. *Dactylopterus volitans* Linnaeus. Note aeus.] Archivio Zoologico Italiano, Naples, **26**: 121–151, pls. 6–7.
V. *Orthogoriscus mola* Linnaeus. Note VI. *Balistes capriscus* Linn.
SOI(45); LS(121); SZ(10) [Pagination] misread on the beginning page (p. 10); CL; BCM. The number 10 on the beginning page is a folder number for bookbinding. This paper includes six sections with respective in-text subtitle, above. The main text title gives at its end (in parentheses) the sum of these subtitles, which is abridged here, as shown as above.
[Note 1] The genus *Lophotes* Bosc, 1817, is a synonym of *Lophotus* Giorna, 1809; the *Lophotes cepedianus* of Valenciennes, 1845 in Cuv. Val. (= *Lophotus cepedianus* Cloquet, 1823) is a synonym of *Lophotus lacepedei* Giorna, 1809. (PALMER, 1973c) [Note 3] For the species name in the text title, see Entry [1913a]. [Note 4] For the species name in the text title, misprinted (*voitans*), see Entry [1933c] on further details. [Note 5] For the genus name in the text title, see Entry [1919]; the *O. mola* of Costa, 1850 (= *Tetraodon mola* Linnaeus, 1758) is revised as *Mola mola* (Linnaeus). (TORTONESE, 1973c) [Note 6] The *B. capriscus* Gmelin, 1789, in Linnaeus is a synonym of *Balistes carolinensis* Gmelin, 1789. (TORTONESE, 1973b)
- 1939e La schiusa delle uova nei Teleostei. [Hatching of teleostean eggs.] Atti del 2° Convegno di Biologia marina e sue applicazioni alla pesca, tenuto in Messina nei giorni 30 maggio–1 giugno 1939. 6 p.
SOI(46); LS(122); SZ not registered.
- 1940a Uova e larva appena schiusa di *Lophotes cepedianus* (Giorna). [Eggs and just hatched larva of *Lophotes cepedianus* (Giorna).] R[egio] Comitato Talassografico Italiano, Memoria **272**: 1–8, 1 pl.
SOII(35); LS(123); SZ not registered; CL [Text pagination] p. 1–6; BMD.
For the genus and species names in the text title, see Entry [1939d (Note D)]
- 1940b Sviluppo embrionale e larva appena schiusa di *Scomberesox saurus* (Flem.) [Embryonic development and just hatched larva of *Scomberesox saurus* (Fleming).] R[egio] Comitato

grafico Italiano, Memoria **276**: 1–8, 1 pl.

SOII(36); LS(124); SZ not registered; CL [Taxonomic authorship] rearranged (Walb.) by the editors; [Pagination] p. 1–6, 8 figs.; BMD. The plate includes 8 figures.

The authorship of the *S. saurus* is Walbaum, 1792, but not Fleming; the *Esox saurus* Walbaum, 1792, was revised as mentioned above by Fries, Ekström and Sundevall, 1893. (PARIN, 1973)

1940c Divisione: Zeomorphi Regan. in Uova, larve e stadi giovanili di Teleostei... [Division: Zeomorphi Regan. in Eggs, larvae and juvenile stages of teleosteans...] Fauna e flora del Golfo di Napoli, Monografia **38** (1940): 461–470, figs. 287–295, pl. 36 [with 2 pages of plate legend].

SOIII(7); LS(125); SZ not registered; CL [Publication date] 1956; [ex-text element] pl. 34; LIM.

See also a bibliographic annotation on this monograph in Entry [1931e].

The Zeomorphi is an order name proposed by Regan, 1910. (BERG, 1947)

Table 1. Scope of research subjects (Subjects) treated in Sanzo's 122 contributions (Contributions) that were issued during the period from 1900 to 1940. Contributions: for detail of entry code, see text; figures in parentheses, number of in-test subtitles in the article concerned; figures in brackets, sum of articles in each subject. Others in the column Subject: ICBM, Ist. Cent. Biol. Mar. Messina.

Subjects	Contributions
Chemistry	
Organic chemistry	1931b, c [2]
General zoology	
Physiology:	
Invertebrates	1903a, b, 1907a [3]
Vertebrates	1900, 1907b, c [3]
Embryology	1904a [1]
Early life history:	
Invertebrates	1929f, 1937a [2]
Technique invention:	
Microscopy	1904b [1]
Embryology	1905d, 1936b, 1939b [3]
Histology	1905d, f [2]
Planktology	1928a, g [2]
Pathology:	
Invertebrates	1905c [1]
Ichthyology	
Early life history/ Cruise report	1905b, e, 1909a,b, 1910b(3), c, d, 1912b, c, d, 1913a, b, 1914, 1915a, b, c(5), 1915d(2), e, f(3), 1917b, c, 1918a, b, c, d, e, f, g(13), 1919, 1922, 1924a, b, 1925a, b, 1926b, c, d, e, 1927a, d, 1928c, d, e, f, 1929c, 1930b, c, d, e, f, 1930g, i, j, 1931a, d, e, f, g, i, 1932a, b, c, d, e, f, g, h, 1933a, b, 1934, 1935, 1936a, c(2), 1937a, b, 1938a, b, c, 1939a, c, d(6), e, 1940a, b, c [85]
Physiology	1928b, 1929e, 1930k [3]
Morphology	1911, 1912a, 1929d [3]
Biology & fishery	1910a(3), 1921, 1927b, c, 1929a, b [6]
Technique invention	1931h [1]
Others	
Cruise project	1926a, 1930a [2]
ICBM	1917a, 1930h [2]

Table 2. Higher taxa (Names) referred in the text titles of Sanzo's 33 contributions (Contributions) on marine fishes. Contributions: for detail on entry codes, see text. Remarks: name in *italic*, original shown in text title(s). For SPARTÀ (1941) see also entries concerned.

Names	Contributions	Remarks
Selachii	1905e (yolk sac disposition)	<i>Selacide</i> [?!=Selacei; cf. PALOMBI and SANTARELLI, 1953]
Teleostei	1915c (egg development), 1928b (specific gravity of eggs), 1929d (cutaneous skeleton), e (specific gravity of eggs), 1936a (eggs in general), 1939d (rare records of larvae), 1939e (hatching)	
Carangidae	1930j	
Macrouridae	1932h	<i>Macruridae</i> ; cf. SPARTÀ (1941)
Mugilidae	1932c, 1936c	
Muraenidae	1905b	<i>Murenoidi</i> ; for detail, see annotation for this entry
Plectognathi	1926b, 1927d, 1930c, d	
Salmonoidei	1931e	
Scombroidei	1909b, 1910b, d, 1932a	<i>Scomberoidi</i>
Scopelini	1915a, b, f, 1918g	
Sternoptychidae	1912d, 1928c, 1930g, 1935	
Stomiidae	1928c, 1930g, 1935	[not referred in text of any entry]
Stomiatoidei	1931f	
Zeomorphi	1940c	

Table 3. Species (Names) referred in the text title and/or in-text subtitle of Sanzo's 76 contributions (Contributions) on marine fishes. Contributions: for detail on entry codes, see text; when the names are cited only in the in-text subtitle, related entry code is shown in *italic*. Remarks: Clofnam references; figures in parentheses, chapter number in the Clofnam, I (HUREAU and MONOD, 1973).

Names	Contributions	Remarks
<i>Anguilla anguilla</i>	1926e, 1929b, 1931g	BLACHE, BAUCHOT and SALDANHA (71)
<i>Argyropelecus hemigymnus</i>	1924b, 1928c	BAIRD (38)
<i>Aulopus filamentosus</i>	1915b, f, 1938c	NIELSEN (50)
<i>Auxis bisus</i> (= <i>Auxis rochei</i>)	1909a	POSTEL (157)
<i>Balistes capriscus</i> (= <i>Balistes carolinensis</i>)	1939d	TORTONESE (201)
<i>Bathophilus nigerrinus</i>	1915a, c, e, 1918d	MORROW (42)
<i>Brama raji</i> (= <i>Brama brama</i>)	1928f	MEAD (133)
<i>Carcharodon rondeletii</i> (= <i>Carcharodon carcharias</i>)	1912c	SPRINGER (7)
<i>Centrolophus pompilus</i> (= <i>Centrolophus niger</i>)	1932g	HAEDRICH (176)
<i>Chauliodus sloani</i>	1914, 1915c, 1918c	MORROW (40)
<i>Chlorophthalmus agassizi</i>	1915b, f	NIELSEN (55)
<i>Dactylopterus volitans</i> (= <i>Cephalacanthus volitans</i>)	1934, 1939d	MONOD (193)
<i>Echeneis naucrates</i>	1926c, 1927a, 1930b	LACHNER (200)
<i>Eretmophorus kleinbergi</i>	1939d	COHEN (103)
<i>Exocoetus</i> sp.	1930k	PARIN (92)

Names	Contributions	Remarks
<i>Gobius</i> spp.	1911	17 spp.; MILLER (162)
<i>Gonostoma denudatum</i>	1912a, 1932d	WITZELL (37)
<i>Ichthyococcus ovatus</i>	1913a, 1918e, 1930g, 1939d	WITZELL (37)
<i>Lophotes cepedianus</i> (= <i>Lophotus lacepedei</i>)	1939d, 1940a	PALMER (109)
<i>Maurolicus amethystinopunctatus</i> (= <i>Maurolicus muelleri</i>)	1924a	WITZELL (37)
<i>Maurolicus pennanti</i> (= <i>Maurolicus muelleri</i>)	1935	WITZELL (37)
<i>Mugil cephalus</i> (= <i>Mugil cephalus cephalus</i>)	1930f, 1936c	TREWAVAS (181)
<i>Mugil chelo</i> (= <i>Chelon labrosus</i>)	1936c	TREWAVAS (181)
<i>Mugil labeo</i> (= <i>Oedalechilus labeo</i>)	1937b, 1938a	TREWAVAS (181)
<i>Myctophum alatum</i> (= <i>Lampanyctus alatus</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum benoiti</i> (= <i>Hygophum benoiti</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum benoiti hygomi</i> (= <i>Hygophum hygomi</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum coccoi</i> (= <i>Gonichthys coccoi</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum crocodilum</i> (= <i>Lampanyctus crocodilus</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum dofleini</i> (= <i>Lobianchia dofleini</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum elongatum</i> (= <i>Notoscopelus elongatus</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum gemellari</i> (= <i>Lobianchia gemellari</i>)	1918g, 1931d	KREFFT and BEKKER (58)
<i>Myctophum glaciale</i> (= <i>Benthoema glaciale</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum madarense</i> (= <i>Ceratoscopelus madarensis</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum metopoclampus</i> (= <i>Diaphus metopoclampus</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum rafinesquei</i> (= <i>Diaphus rafinesquei</i>)	1918g	KREFFT and BEKKER (58)
<i>Myctophum rissoi</i> (= <i>Electrona rissoi</i>)	1918g, 1939c	KREFFT and BEKKER (58)
<i>Naucrates ductor</i>	1931a	HUREAU and TORTONESE (131)
<i>Orcynus germo</i> (= <i>Thynnus (Germa) alalunga</i>)	1910b, 1925a, 1933a	POSTEL (157)
<i>Orcynus thynnus</i> (= <i>Thunnus (Thunnus) thynnus</i>)	1910a, b, 1927b, 1929c, 1932f	POSTEL (157)
<i>Orthogoriscus mola</i> (= <i>Mola mola</i>)	1939d	TORTONESE (207)
<i>Orthogoriscus</i> spp. (= <i>Mola</i> spp.)	1919	TORTONESE (207)
<i>Paralepis hyalina</i> (= <i>Sudis hyalina</i>)	1917b	POST (63)
<i>Paralepis rissoi</i> (= <i>Notolepis rissoi</i>)	1917c	POST (63)

<i>Names</i>	<i>Contributions</i>	<i>Remarks</i>
<i>Paralepis sphyraenoides</i> (= <i>Lestidiops sphyraenoides</i>)	1918a	POST (63)
<i>Pelamys sarda</i> (= <i>Sarda sarda</i>)	1910b, 1932e	POSTEL (158)
<i>Regalecus gladius</i> (= <i>Regalecus glesne</i>)	1926d	PALMER (106)
<i>Regalecus glesne</i>	1925b	PALMER (106)
<i>Remora remora</i> (= <i>Echeneis remora</i>)	1928d	LACHNER (200)
<i>Saurenhelys cancrivora</i>	1938b	BLACHE, BAUCHOT and SALDANHA (80) NIELSEN (51)
<i>Saurus griseus</i> (= <i>Synodus saurus</i>)	1915b, f	
<i>Scomberesox saurus</i> (= <i>Esox saurus</i>)	1940b	PARIN (91)
<i>Scopelus caninianus</i> (= <i>Myctophum punctatum</i>)	1915a, c, d	KREFFT and BUSEKKER (58)
<i>Scopelus gemeralli</i> (= <i>Lobianchia gemeralli</i>)	1931d	KREFFT and BEKKER (58)
<i>Scopelus humboldti</i> (= <i>Myctophum punctatum</i>)	1915a, c, d	KREFFT and BEKKER (58)
<i>Seriorsa dumerilii</i> (= <i>Caranx dumerilii</i>)	1930j, 1933b	HUREAU and TORTONESE (131)
<i>Smaris insidiator</i> (= <i>Centracanthus cirrus</i>)	1939a	TORTONESE, SERTORIO and BAUCHOT (141)
<i>Stomias boa</i> (= <i>Stomias boa boa</i>)	1912b, 1915c, 1918b	MORROW (41)
<i>Stylophthalmus lobiancoi</i> (= <i>Myctophum punctum</i>)	1915c, d	KREFFT and BEKKER (58)
<i>Stylophthalmus mediterraneus</i> (= <i>Symbolophorus veramyi</i>)	1915c, d	KREFFT and BEKKER (58)
<i>Thynnus brachypterus</i> (= <i>Thunnus (Thunnus) thynnus</i>)	1910a	POSTEL (158)
<i>Trachurus mediterraneus</i> (= <i>Trachurus mediterraneus mediterraneus</i>)	1932b	HUREAU and TUSORTONESE (131)
<i>Trachipterus cristatus</i> (= <i>Zu cristatus</i>)	1918f	PALMER (107)
<i>Vinciguerria attenuata</i>	1913b	WITZELL (37)
<i>Vinciguerria poweriae</i>	1913b, 1931f*	WITZELL (37) *after WITZELL (1973: 122)
<i>Xiphias gladius</i>	1910c, 1921, 1922, 1927c, 1929a, 1930e, i	TORTONESE (161)
<i>Zeus faber</i>	1928e, 1931i	WHEELER (120)

Based on this listing, contributions by Sanzo are enumerated 122 articles, as summarized as given in Table 1. Among them, 8 articles are subdivided into sections or chapters with their relative in-text subtitle. These articles are Entries [1910a (3 sections), 1910b (3 sections), 1915c (5 sections), 1915d (2 sections), 1915f (3 sections), 1918g (13 sections), 1936c (2 sections), and 1939d (6 sections)]. When all the sections are considered as independent each other, his articles are totally of 151. SPARTÀ

(1941) considered such a section as it were an independent article, but only for Entry [1918g], or LS(43-54, or 12 entries). As mentioned above, this paper [1918g] includes 13 sections. The 13th section was overlooked by the preceding compiler. If his arrangement is not appropriate for the articles, his listing comes to contain 114 of the 122 articles listed here.

3. Range of Sanzo's interest

The works listed here tell us that Sanzo had

expressed a continuing interest in a wide range (Table 1) of natural sciences, while his bio-medical career had focused on ichthyology in the framework of both elasmobranch and teleostean fishes (Table 2). His speciality was apparently in embryology or early life history (85 of 122 articles) of marine fishes, and naturally extended to domestic marine fishery (6 articles). After all, those works cover more than 80 genera (Table 3) in the ichthyological taxa. It is noteworthy here that he contributed to another field or fish morphology, of which the next section is given for the detail. His interest attached moreover to other animals, and 9 works were published on Scyphomedusae, Anthozoa, Pelesypoda, Cephalopoda, Sagittoida and Amphibia.

4. Morphological contributions

Sanzo directed his special attention (Table 1) not only to early life history, but also to morphology of fishes. This is in relation to the lateral system of 17 *Gobius* species (Gobiidae) [Entry 1911], the luminous organ of *Gonostoma denudatum* larvae (Gonostomatidae) [Entry 1912] and the cutaneous skeleton in the initial stage of teleostean fishes [Entry 1929d]. The latter two are apparently in connection with early life history as well. Concerning the other, or the former work, it is rather unique among all other works, because the work is exactly in relation to systematic ichthyology, while he (1911: 252) suggested an interrelationship of the work to his studies on Myctophidae. He had never paid his attention to this scientific field so far, except another case where he guided his academic successors (MORTARA, 1918; LAMBERTENGI, 1919) in a study of a similar theme.

As referred already (TAKAGI, 1988), the unique work of systematics was not necessarily estimated by international researchers before the 1950s. A higher estimation of it was probably established by BERTIN and ARAMBOURG (1958: 2447, fig. 1760), from the viewpoint of the importance of extraordinarily developing of the pit line system in the gobioid fishes. It may be remembered here that his connection (SANZO, 1911: 253) formed with a French colleague (Louis Fage) during the

preparatory period of the work.

According to his own account (SANZO, 1911, loc. cit.) and available documents, the Stazione Zoologica in Naples might play an important role in accomplishment of the work. He (1911; loc. cit.) noted that, besides such a support as the direction of his professor at the Regia Università di Palermo, the work was prepared mostly for the last three years by the courtesy of the Station. The archive documents of the Station tell us that Sanzo was registered as visiting researcher three times, that is, in 1903 (for 110 days from Messina), 1908 (for 86 days from Palermo) and 1910 (for 11 days from Palermo). His mention cited above suggests that the latter twice visits directly did for his research. And big results of the research was published on the Station's organ.

Finally, it is interesting that he was qualified in the very year of 1911 (Appendix 1) after a competition as professor at the newly established Regio Comitato Talassografico Italiano, and actually in 1916, nominated as Professor-Director at the Istituto Centrale di Biologia Marina in Messina, under government of the Committee. The gobiological work must be the keynote of the dissertation for professorship besides his preceding numerous works.

5. Taxonomic topics

As far as our survey goes, Sanzo made no taxonomic contribution, though we can see a few contrary indications. According to JORDAN (1963: [627] 127), Sanzo is to have described the genus *Stylophthalmooides* in 1922. GOLVAN (1965) followed after JORDAN (1963, loc. cit.) in his catalogue of fish genera. JORDAN (1963: 790) additionally referred the original description of the genus, as "... Mem. Acad. Roma, 1920 [not 1922]; orthotype *S. lobiancae* [= *lobiancae*] Sanzo (Larvae of some Stomiid)." Nevertheless, the serial mentioned there is difficult to be identified among others. Recently, PAXTON (1979) gave a solution for this confusion, with ESCHMEYER (1990). PAXTON (1972: 43; 1979: 15) and ESCHMEYER and BAILEY (in ESCHMEYER, 1990: 393) pointed out that the genus was described in 1912 by Mazzarelli. As cited above (Entries [1915c, d]), SANZO referred to 2 species of this genus.

On the other hand, the vital activity of Sanzo seems to have inspired taxonomists. According to the Clofnam, successive researchers dedicated to him 3 species names, These species belong to Apogonidae (*Microichthys sanzoi* Spartà, 1950), Gobiidae (*Gobius sanzoi* de Buen, 1918) and Gonostomidae (*Vinciguerria sanzoi* Jespersen et Tåning, 1919), respectively.

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Appendix 1. Brief personal record of Prof. Luigi Sanzo

- 1874 Born at Capizzi in the region of Nebrodi (Caronie) of the province of Messina on 26 October 1874
- 1897-1899 Nominated as Intern at the Institute of Pharmacology of the Royal University of Messina, directed by Prof. G. Gaglio. (Interno nell'Istituto di Farmacologia della Regia Università di Messina)
- 1899 Did Degree in medicine and surgery with excellent marks
- 1900 Nominated as Personnel of the Medical Museum at the Royal University of Messina (Personale del Gabinetto di Materia medica della Regia Università di Messina)
- 1901 Did Degree in natural sciences with highest marks
- 1902 Won at the competition for qualification and examination at Rome for professorship of natural sciences in secondary schools (Vincitore nel concorso per titoli ed esami a Roma per cattedre di scienze naturali nei licei)
- Nominated as Assistant of Zoology and Comparative Anatomy at the Institute of Experimental Pharmacology of the Royal University of Messina, directed by Prof. A. Benedicenti (Assistente di Zoologia ed Anatomia Comparata nell'Istituto di Farmacologia Sperimentale della Regia Università di Messina)
- 1903 Registered as visiting researcher (Register No. 1426) of the Anton Dohrn Zoological Station in Naples during the period from 9 July to 26 October 1903 (Ricercatore ospite della Stazione Zoologica "Anton Dohrn" di Napoli)
- 1905 Nominated as Lecturer of Zoology and Comparative Anatomy at the Institute of Experimental Pharmacology of the Royal University of Messina, teaching vertebrate embryology (Incaricato/Libera docenza di Zoologia ed Anatomia Comparata nell'Istituto di Farmacologia Sperimentale della Regia Università di Messina)
- 1906 Married with Miss Isabella Salvo at the Chiesa di S. Teresa di Riva in Parelmo (Via Liberià 101) on 4 September 1906 [No trace of the church and the street is found in the recent Palermo City, as far as our personal survey

- goes]
- 1907 Nominated as Lecturer and Assistant of Comparative Anatomy and Physiology at the Institute of Zoology of the Royal University of Palermo, directed by Prof. F. Raffaele (Libero docente ed Aiuto di Anatomia e Fisiologia Comparata nell'Istituto di Zoologia della Regia Università di Palermo)
- 1908 Registered as visiting researcher (Register No. 1852) of the Anton Dohrn Zoological Station in Naples from Palermo during the period from 6 August to 30 October 1908 (Ricercatore ospito della Stazione Zoologica "Anton Dohrn" di Napoli)
- 1910 Registered as visiting researcher (Register No. 2066) of the Anton Dohrn Zoological Station in Naples from Palermo during the period from 18 to 28 August 1910 (Ricercatore ospito della Stazione Zoologica "Anton Dohrn" di Napoli)
- 1911 Won at the competition for Chief Biologist-Specialist or Professor at the Royal Oceanographic Committee of Italy (founded in 1910 at Naples) for the Central Institute of Marine Biology, a projected laboratory in Messina (Vincitore nel concorso a Biologo specialista capo del Regio Comitato Talassografico Italiano per il Istituto Centrale di Biologia Marina in Messina)
- 1916 Nominated as Director at the Central Institute of Marine Biology in Messina, Royal Oceanographic Committee of Italy, actually the Experimental Institute of Oceanography in the National Council of Researches (Istituto Sperimentale Talassografico nelle Consiglio Nazionale delle Ricerche), on 10 December 1916, recommended by Profs. B. Grassi and F. Raffaele (Direttore al Istituto Centrale di Biologia Marina in Messina del Regio Comitato Talassografico Italiano)
- 1932 Nominated as Member of the National Committee for Biology in the National Council of Researches (Membro del Comitato Nazionale per la Biologia del Consiglio Nazionale delle Ricerche)
- 1933 Won Prize for physical and natural sciences for the year 1933 by the Italian Society of Sciences (Premio per le scienze fisiche e naturali per l'anno 1933 dalla Società Italiana delle Scienze)
- 1935 Nominated as Honorary member of the Société Zoologique de France, offered by Prof. M. Caullery
- 1939 Nominated as Member of the Committee for Research on Marine Biology applied to Fishery of the Commissionership General for Fishery (Membro del Commissione per gli Studi sulla Biologia Marina applicata alla Pesca del Commissariato Generale per la Pesca)
- 1940 Deceased after shortest illness in Messina on 10 December 1940

資 料

第39巻第 1 号掲載欧文論文要旨

Laurent Seuront*: 海洋の微細構造 : 生態系にとってなぜ重要なのか?

乱流は、一般に均質な過程として考えられている。乱流の生態系への影響は、乱流エネルギーの逸散率の平均値が推定されている。ところが、乱流は極めて間欠的のプロセスである。マルチフラクタルの概念を用いて乱流の間欠性が与える影響として、1) 遊泳力をもたない植物プランクトンへの栄養塩のフラックスを6から62%増加させる、2) 植物プランクトンの凝結を25から48%、その結果として植物プランクトンの蜆集体積を22から41%減少させる、3) 乱流成分による捕食者-被捕食者間の遭遇確率を25-50%減少させることを示した。

(*東京水産大学海洋環境学科 〒108-8477 港区港南4-5-7 現所属 : Station Marine de Wimereux-CNRS ESA 8013 ELICO, Universit des Sciences et Technologies de Lille, 28 avenue Foch-BP80, 62930 Wimereux, France)

塩本明弘*・橋本慎治*: 1992年7月の沖合域の親潮水域におけるサイズ分画したクロロフィル *a* と基礎生産力

1992年7月の沖合域の親潮水域に設けた4測点の、100, 30, 10および1%の光深度において、 <2 , 2-10および10-200 μm サイズのクロロフィル *a* 濃度と基礎生産力を測定した。ある観測点の10%光深度での結果を除くと、観測点や光深度によらずクロロフィル *a* 濃度、基礎生産力ともに <2 あるいは2-10 μm サイズが占める割合が最も高かった。これらのサイズがクロロフィル *a* 濃度と基礎生産力は、平均値で見るといずれも40-50%で、10-200 μm サイズが占める割合は平均値で10-15%であった。例外と見られたある観測点の10%光深度においては、10-200 μm サイズがクロロフィル *a* と基礎生産力に占める割合は45%であった。この例外的な結果は、より高い濃度の窒素態栄養塩(主に硝酸)の利用が可能で、10-200 μm サイズの植物プランクトンにとって光が制限となっていなかったことによると考えられる。夏季の沖合域の親潮水域では、一般に小型の植物プランクトンが植物プランクトン群集の現存量および基礎生産に大きく寄与し、十分な光深度がある深さでは高い濃度の硝酸塩が利用可能な場合に、大型の植物プランクトンも植物プランクトン群集の現存量および基礎生産に大きく寄与することが示唆された。

(水産庁遠洋水産研究所 〒424-8633 静岡県清水市折戸5-7-1)

高木和徳*: ルイジ・サンツォ教授業績目録の校訂と校註

ルイジ・サンツォ教授(1874-1940)の業績目録を、入手できた未公刊物を含む原資料に基づいて校訂した。彼の研究領域は動物学の幅広い分野に亘っているが、その重点は深海域から沿岸域にかけて生息する真骨魚類の初期生活史を主体とする海洋生物学に置かれている。1900年から1940年までに公表された彼の全業績は122篇であることが明らかにされた。生涯に亘る研究活動の中で、17種類のハゼ科魚類についての比較形態学の1篇(1911)に見られる彼の興味は特異なものといえる。その興味の動機は彼の研究歴から探れる。

(*オイディスク・トウキョウ 〒104-0051 中央区佃2-1-2(3311))

学 会 記 事

1. 2000年12月19日(火) 東京水産大学において学会賞受賞候補者推薦委員会(第2回)が開かれ、評議員から推薦のあった候補者について審議の結果、寺崎誠会員(東大海洋研)を受賞候補者と決定し、会長へ報告することとした。

2. 評議員宛に「2001年度日仏学者交換公募」の候補者の推薦依頼を行った。

3. 新入会員(正会員)

氏名	所属・住所等	紹介者
神田穰太	東京水産大学海洋環境学科 〒108-8477 港区港南4-5-7	前田 勝
内藤靖彦	国立極地研究所資料系 〒173-8515 板橋区加賀1-9-10	山口征矢

4. 所属・住所等変更
(正会員・受付順)

守安実己郎 Department of Fisheries and Oceans
Science Branch, Gulf Management Region
P.O.Box 5030/343 Universite Avenue
Moncton, New Brunswick E1C9B6,
Canada
関 文威 〒166-0015 杉並区成田東4-32-9

5. 社名変更(賛助会員)

国土環境(旧:新日本気象海洋)平成13年1月より

6. 退会(正会員)

江口一平, 鎌谷明善, 鈴木 誠, 畑 幸彦, 竹松 伸

7. 受贈図書(受付順)

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Journal of the Korean Society of

Oceanography 35(4)

Ocean Research 22(2)

Archives Scientifiques 17(1)

お知らせ

公益信託ミキモト海洋生態研究助成基金 平成13年度研究助成候補者の公募

御木本真珠発明100周年を記念して、平成4年7月1日に設立された「公益信託ミキモト海洋生態研究助成基金」の第9回助成対象者が募集されます。

大学等の研究期間の研究者または研究グループ、中、高等学校の教諭、生物クラブなどで、潮間帯から浅海にわたる海域を対象とした、1)生物に関する調査・研究、2)生物の生息環境に関する調査・研究、3)生態の保全のあり方に関する調査・研究に対し、総額150万円が助成されます。

応募締切は平成13年5月10日。助成金の支給は平成13年7月中旬を予定しています。募集要項、申請書等は下記あてにハガキでご請求ください。

【申請書等の請求先】

〒110-8676 東京都台東区下谷3-10-10
財団法人自然環境研究センター内
公益信託ミキモト海洋生態研究助成基金事務局
電話03-5824-0955 FAX03-5824-0956

生物系特定産業技術研究推進機構、松下電工、ミサキ電気と共同で 環境を配慮した「閉鎖循環式陸上養殖システム」の研究開発会社を設立

生物系特定産業技術研究推進機構（略称：生研機構 東京都港区）と松下電工、ミサキ電気（本社 兵庫県津名町）では、人工海水を濾過循環し、ヒラメなどを育てる閉鎖循環式陸上養殖システムを研究開発する「株式会社 陸上養殖工学研究所」を、2001年2月1日に設立（本社 松下電工本社内）した。

松下電工では、閉鎖循環式陸上養殖システムを、3年前より養殖技術の研究機関として高い実績のある近畿大学と共同研究を行うとともに、養殖に長年従事し現場経験豊富な養殖専門業者と連携し、現場の実態やニーズ把握を進めてきました（実証実験場として昨年10月、滋賀県高島郡新旭町に「近江フィッシュファーム」を開設、ヒラメ、オコゼ、トラフグの養殖を行っており、予想以上に順調に成長しています）。

松下電工では、今までに蓄積してきた技術をベースに、環境を配慮した「閉鎖循環式陸上養殖システム」を生研機構が昨年4月5日から4月30日にかけて公募した出資事業対象として応募。応募テーマの中から審査を重ねて選定され、このたび出資決定を受け新会社設立の運びとなり、これを機に、21世紀の養殖技術と注目される「閉鎖循環式陸上養殖システム」の実用化を目指すこととなった。

閉鎖循環式陸上養殖システムの研究開発

1) 目的

我が国の水産業においては、①水産資源の減少、②国際的な漁業制限、などを背景に、今後、つくり育てる漁業＝

栽培養殖の位置づけがますます重要になります。しかし、現在の養殖は、養殖に適した沿岸海域がほぼ満限にある中、①赤潮被害、②病気の多発や魚の排泄物、残餌などによる海洋汚染など、多くの問題を抱え安定した経営が困難となっています。これらの課題の克服が、今後の養殖事業の進展にとって不可欠な状況です。

これらの問題解決に有効な養殖手段である「閉鎖循環式陸上養殖システム」＝汚染の恐れがない人工海水などを濾過して、継続使用する養殖手法を実用化するために必要な安定的な飼育水浄化技術および飼育管理の自動化技術などを開発します。

2) 効 果

閉鎖循環式陸上養殖が実用化することで、従来の養殖方式と比較し次のような効果が期待できます。

- ①飼育環境の調節が自由にできる。
- ②病気の発生が少ない高効率な養殖生産が可能になる。
- ③安定的な養殖経営ができる。
- ④立地制限がなく、養殖業への新規参入の促進、中山間地域の振興が図れ、海面以外の新たな漁業生産・供給の場として、安定供給の一助となる。
- ⑤排泄物、残餌などによる海洋・河川の汚染を引き起こさず、環境保全全面での貢献が期待できる。

3) 研究開発する技術

- ①生物的浄化技術＝排泄物、残餌などの汚染物質を分解する細菌を濾材に付着増殖させ、生物膜を作り浄化する技術として、生物の付着性に優れた濾材の内部に包み込む形で生物を固着する技術。
- ②物理的浄化技術＝汚染物質を分解促進するための飼育排水の電気分解利用技術。
- ③微細気泡発生技術＝微細な気泡に汚染物質を吸着させ、浮上分離する技術。
- ④捕捉性・メンテナンスに優れた物理濾材、耐久性・処理能力に優れた物質分解膜などの開発。
- ⑤高効率安定飼育、省力化（人件費削減）のため、ネットワーク通信による水質など、重要項目の一括管理（異常検出）、データに基づく養殖条件の自動制御システム、自動給餌・残餌排出システム、低コスト殺菌技術の開発。

4) 本件に関する問い合わせ先

一般からのお問い合わせ先

陸上養殖工学研究所（TEL：06-6906-3410）

報道関係お問い合わせ先

松下電工株式会社 大阪広報部（TEL：06-6909-7187）

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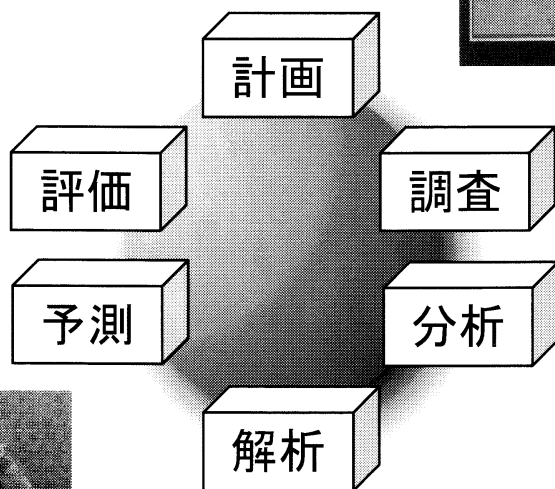
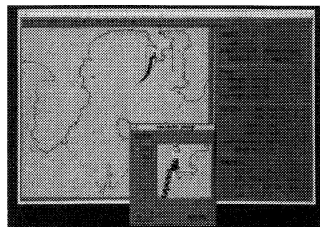
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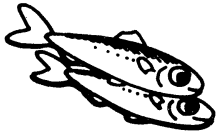
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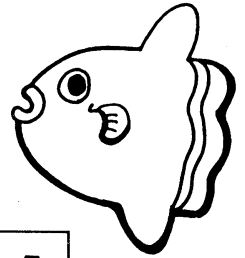
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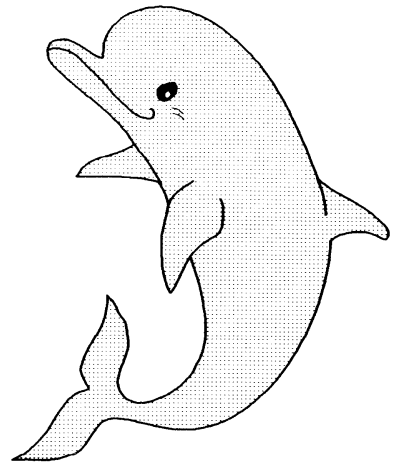
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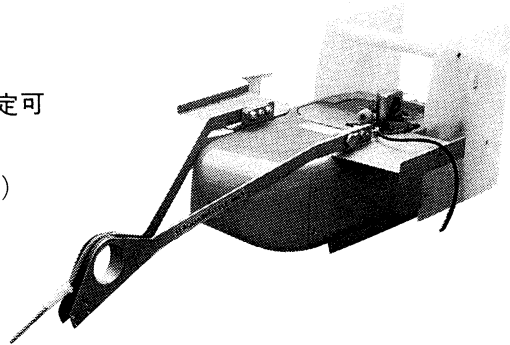
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(正会員・学生会員)

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氏 名		
ローマ時		年 月 日 生
住 所 〒		
勤務先	機関名	
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自 宅 住 所 〒		
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日 仏 海 洋 学 会

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