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Plankton as indicators of coastal water bodies during south-west to north-east monsoon transition at Kalpakkam

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In the coastal waters of Kalpakkam, a water body characterized by high salinity, rich nutrients and low temperature (southern-sub surface water SSW) was seen during the early half of September when the pole-ward current prevailed. This was replaced by low saline, low nutrient and relatively high temperature water (northern-surface water NSW) during early October when the current was equator-ward. This reversal in current direction is induced by the north-east monsoon winds during the SW to NE monsoon transition. It is also observed that SSW in the Kalpakkam coast during the later half of September was characterized by the presence of pennate diatoms *Nitzschia closterium*, *Asterionella glacialis* and *Thalassionema nitzschiodes*. However, NSW in this coast in early October is characterized by the presence of centric diatom *Skeletonema costatum*. The two water bodies also have a characteristic zooplankton population, the SSW is rich in meroplankton and the NSW is poor in meroplankton. Thus, the pennate diatom *N. closterium*, *A. glacialis* and *T. nitzschiodes* would be considered as indicators of SSW and centric diatom *S. costatum* as the indicator of NSW.

THE Bay of Bengal experiences a biannual change in the current direction of coastal water as a result of the existing wind namely north-east and south-west monsoons[1]. Extensive studies were made to identify the movement of water masses during this period[1–6]. Temperature and salinity were used as indicators of movement of water masses of this coast by many authors[5,6]. Besides the T–S diagram, many authors used plankton as the indicator of water masses[7–17]. We present here data on the identification of water bodies using plankton as indicators in the western boundary of Bay of Bengal at Kalpakkam.

Water sampling was carried out from a jetty at Kalpakkam extending about 500 m into the sea (Figure 1). The hydrographic parameters such as temperature, salinity, dissolved oxygen (DO), chlorophyll *a*, nutrients (ortho phosphate, reactive silicate, nitrate, nitrite and ammonia) and total suspended solid (TSS)[18] and biological components such as phyto and zooplankton composition[19] of the water column were monitored on every alternate day from 4 September 1996 to 22 October 1996. Coastal current direction as well as its speed was monitored using a drift bottle technique[20]. The period when the coastal current direction was towards north was treated as early transition period and the period when it flowed towards south was treated as late transition period. All measurements were made in the morning hours, i.e. between 0700 and 0800 h.

The current direction changed from north to south on 4 October 1996 (Figure 2, subject to an error of a day). The current velocity was relatively high during the early transition period. However, as time passed, the velocity reduced. The current speed was nearly zero for a couple of days before the direction reversed and the speed increased. After the change in the direction from north to south (pole-ward to equator-ward), again the velocity increased. Surface water temperature during the early transition period was relatively low as compared to late transition period. On the contrary, salinity values were higher (32.59 ± 0.19 ppt) during the early transition period than those during the late transition period (30.7 ± 1.65 ppt). Though dissolved oxygen did not

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show any significant difference between early and late transition periods, the values were relatively high during late transition period. With regard to nutrients, all of them showed a relatively high value during the early transition period than those during the late transition period (Table 1). The differences in concentration of nitrate and nitrite were most remarkable that they were nil or very low during the late transition period while high during early transition period (Table 1). Chlorophyll *a* and diatoms were more in the early transition period than in the late transition period.

A marked variation in the phytoplankton species composition was observed between the early and late transition periods (Table 2). That is, when pole-ward current existed, *Thalassiosira nitzschiodes*, *Nitzschia closterium* and *Asterionella glacialis* were the abundant species. However, when equator-ward current existed, the species *Skeletonema costatum* was found to be the abundant species. More interestingly, *S. costatum* was not present during the early transition period and *T. nitzschiodes* was absent during late transition period (Table 2).

Zooplankton biomass measured as displacement volume was relatively high during the early transition period (0.64 ± 0.20 ml m^{-3}) than the late transition period (0.36 ± 0.13 ml m^{-3}). The difference was found to be statistically significant (One way ANOVA $P < 0.003$). This was true with the total zooplankton count as well (Table 1).

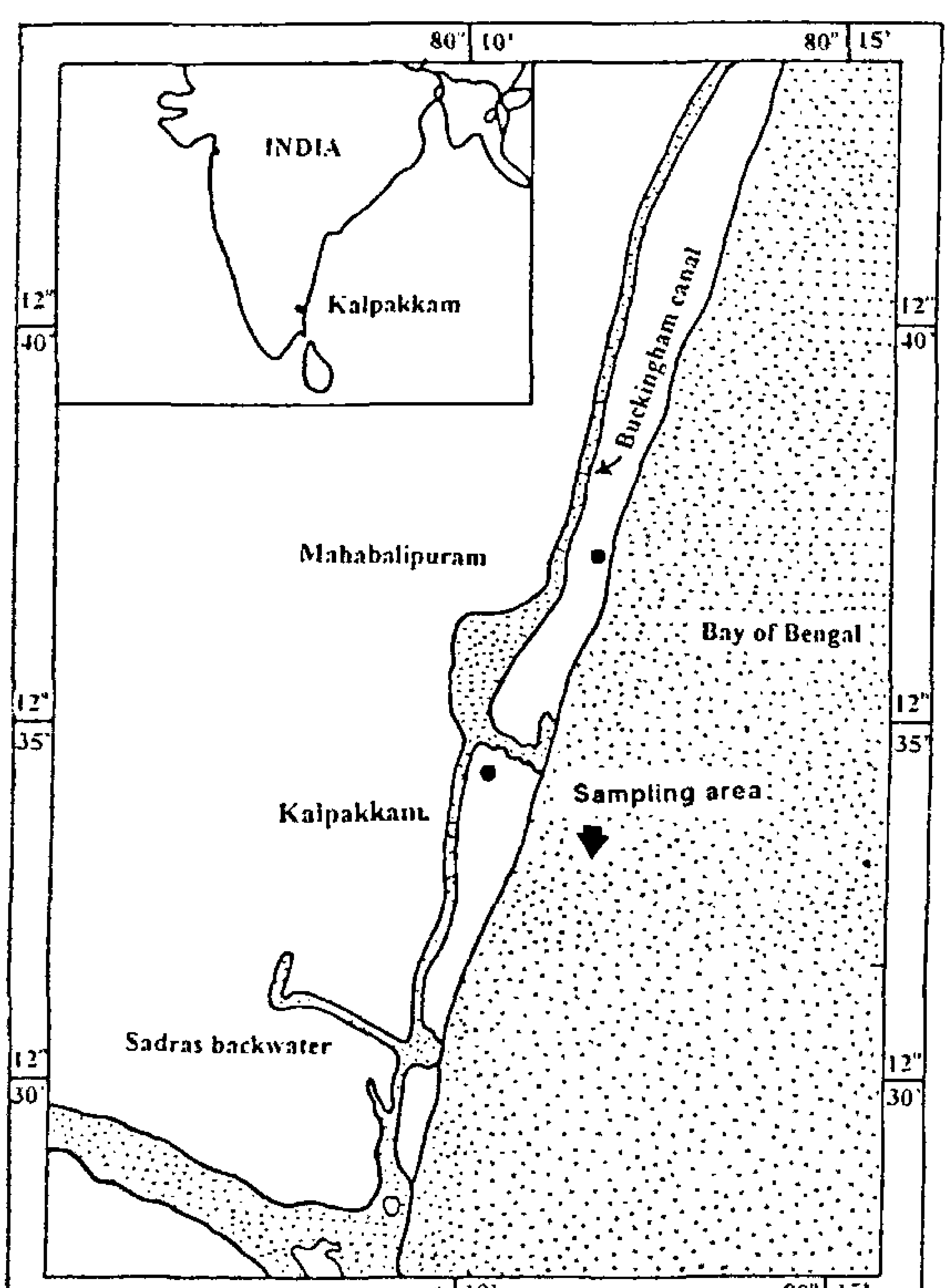

Figure 1. Diagram showing the study and sampling sites.

Among zooplankton, the major groups such as calanoids, chaetognaths, bivalve larvae, gastropod larvae, harpacticoids and cyclopoids which were abundant during the early transition period declined drastically as the late transition period approached. However, groups such as medusae (Hydromedusae, Ctenophores), polychaetes, cladocerans, lucifers and radiolarians were completely absent in the late transition period.

Usually, the onset of north-east monsoon occurs during the late September or early October in the East Coast of India. As a result of this, the surface water of the Bay moves towards south[1-6]. These water movements result in the arrival of new water bodies in coastal area. Although these changes can chiefly be attributed to the wind, the phenomenon such as horizontal density differences also is responsible for this water movement. For example, the perennial rivers that empty at the northern end of the Bay of Bengal cause a horizontal salinity gradient leading to a characteristic mild circulation of water in the Bay[3,4]. The onset of north-east monsoon intensifies this circulation and as a result, a strong coastal current forms along the western boundary of Bay of Bengal. Because of this circulation, the coasts of Tamil Nadu, Andhra Pradesh and Orissa are found to be flushed with different water bodies during October to January. Later, as a result of south-west monsoon (from February to September), the current direction changes which brings bottom water to this coastal area. Some studies using temperature and salinity of the water body have been conducted to explain the circulation pattern in the Bay of Bengal[5,6].

Plankton were used as indicators of water masses off Plymouth by Russel[7,8]. In the English Channel, the zooplankton, *Thysanoessa* sp., *Aglantha*, *Meganyctiphores* and *Clione limacina* were found to be the indicator species of Atlantic cold water mass, while the presence of *Agalma elegans* and *Sagitta serratodentata* indicated the arrival of warmer Gulf stream in the area. It also indicated that *Doliolum* is an indicator of the north Atlantic warm water current. The present study noticed the presence of high saline, nutrient rich and low temperature water during the pole-ward current, which would probably be the upwelled water. Therefore this water is tentatively called as southern-subsurface water (SSW). The studies of Lafond[1], Suryanarayana and Rao[2], Ramaraju *et al.*[5] and Babu *et al.*[6] which illustrated the occurrence of a strong upwelling along this coast during the pre north-east monsoon period have supported this. While the pole-ward current changes to equator-ward current as influenced by the onset of north-east monsoon, less saline water with poor nutrient content and high temperature is being pushed towards the shore from the central Bay of Bengal. Therefore this

Table 1. Range of values of each parameter observed during the early and late transition period with results of one way ANOVA between them

Parameter	Early transition	Late transition	F	P	Significance level
Wind speed (km h^{-1})	8–28.8	7–21.2	1.14	0.296	NS
Current speed (m s^{-1})	0.05–0.44	0.045–0.5	0.46	0.501	NS
Air temperature (°C)	27.3–32.9	27.8–32.1	4.09	0.055	NS
Water temperature (°C)	28.9–29.7	29.1–30.8	16.7	< 0.001	S
Salinity (ppt)	32.33–32.9	27.93–32.13	32.4	< 0.0001	S
Dissolved oxygen (mg l^{-1})	4.086–5.63	4.61–5.13	2.7	0.111	NS
Phosphate (μg at P l^{-1})	0.15–1.7	0.21–0.35	5.5	0.028	S
Silicate (μg at N Si l^{-1})	2.84–15.58	1.2–6.017	16.95	< 0.0001	S
Nitrate (μg at N l^{-1})	0–11.85	0.32–3.07	5.32	0.03	S
Nitrite (μg at N l^{-1})	0–2.41	0–0.08	12.0	0.002	S
Ammonia (μg at N l^{-1})	0.71–28.38	5.46–7.18	7.56	0.011	S
TSS (mg l^{-1})	20–90	26–38	8.99	0.0064	S
Chlorophyll *a* (mg m^{-3})	0.012–0.257	0.042–0.097	1.13	0.29	NS
Phytoplankton (cells ml^{-1})	140–2849	132–676	0.47	0.497	NS
Total zooplankton (nos m^{-3})	2304–6104	796–3288	31.76	< 0.0001	S
Biomass (ml m^{-3})	0.3–1.1	0.2–0.6	13.39	0.0013	S

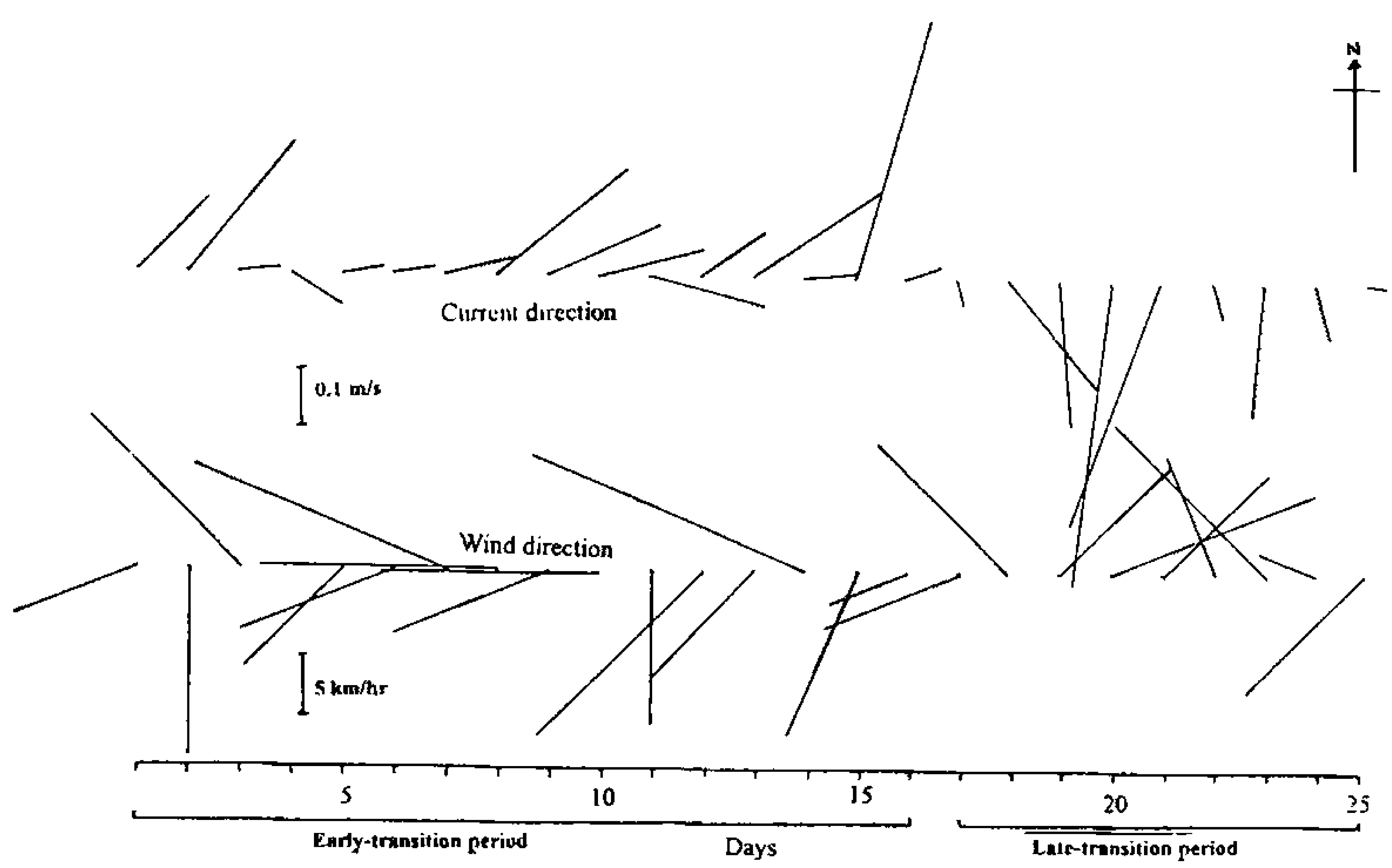

Figure 2. Vector diagrams of coastal current and wind observed during the transition period. (The number of days from 1 to 16 and 17 to 25 were represented as early and late transition periods, respectively.)

water is tentatively called as the northern surface water (NSW).

The present study reveals that the presence of *N. closterium* and *T. nitzschiodes* in this coast indicates SSW (they showed their appearance just before the actual transition or during the transition period) while *S. costatum* indicates the NSW. With regard to zooplankton, *Pleurobrachia* sp., Lucifer and Mysis were abundant in SSW. Russel[8] reported that *Pleurobrachia* sp. could be found in the high saline water, therefore the *Pleurobrachia* sp. is described as an indicator species of SSW. Apart from this, meroplankton were found be high in this water and less in NSW. Therefore, the low density of meroplankton coupled with the absence of *Pleurobrachia* sp. and presence of the diatom *S. costatum* indicates the arrival of NSW. This was found to be true with respect to the long term study on phyto and zooplankton population at this locality covering a period of one year following a bi-weekly sampling schedule (Saravanane, unpublished data). Thus the rapid changes

Table 2. Range of abundance of phyto and zooplankton densities in the early and late transition periods

Phytoplankton species	Early transition (cells ml^{-1})	Late transition (cells ml^{-1})
Pennales		
Thallassionema nitzschiodes	6–142	0
Nitzschia closterium	11–405	0–88
Thalassiothrix longissima	0–60	0–30
Asterionella glacialis	0–1376	0–18
Navicula longa	0–243	0–20
Nitzschia seriata	0–263	0–150
Amphora lineolata	0–25	0
Centrales		
Skeletonema costatum	0	0–159
Thalassiosira subtilis	0–3	0–48
Coscinodiscus excentricus	0–20	0–12
Chaetoceros didymus	0–50	0–94
Chaetoceros pelagicus	0–7	0–134
Zooplankton groups	Early transition (animals m^{-3})	Late transition (animals m^{-3})
Hydromedusae	0–176	0
Holoplankton		
Calanoids	1280–5760	388–3200
Non-calanoids	112–3096	80–576
Meroplankton	56–1376	32–248

in the plankton composition as evidenced by this study can well be treated as an indication of the arrival of these water bodies on this coast.

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Control of coconut black-headed caterpillar (*Opisina arenosella* Walker) by systemic application of 'Soluneem' – A new water-soluble neem insecticide formulation

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The coconut black-headed caterpillar (bhc) *Opisina arenosella* is one of the major pests of coconut palms causing considerable damage to coconut industry. As effective control has so far been elusive, the discovery of a successful method of control of this pest by systemic application of 'Soluneem', the first water soluble, non-toxic neem pesticide is reported. A single dose of systemic administration of the formulation containing 3000 ppm of azadirachtin A in aqueous solution at the base of the trunk translocated the biopesticide to the crown within 24 h. A highly significant reduction in the larval population, moult inhibition, reduction in adult emergence and malformation in the emerged adults was recorded in Soluneem-treated trees. The protection lasted for more than 120 days with no phytotoxic symptoms to the treated palms and Soluneem was safe for natural enemies.

COCONUT black-headed caterpillar (bhc) *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) is one of the major pests of coconut causing considerable dam-

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