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Interactive Comment

Interactive comment on "Long term changes in the ecosystem in the northern South China Sea during 1976–2004" *by* X. Ning et al.

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At first，authors of the present paper appreciate the Referee #1 for spending time to give detailed and very significant comments, and providing some significant opinions. Our answers on the comments are as follows: General comments Reply: In this manuscript very valuable long term changes in physical and chemical parameters in the northern South China Sea (nSCS) during 1976 to 2004 and the responses of nSCS ecosystem were firstly revealed. Although we can not directly show long term series variations of “ancillary data”, such as inter-annual changes of fresh water discharges of the Pearl River, DIN input from the river, air temperature in a site closed to the transect N, etc., required by the Referee, there are many significant literatures to show clear and important results of the authors’ analysis and de-

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scription of the long term trends of these “ancillary” parameters, which strongly support the regulations of the long term series environmental changes we found, and being helpful to interpret the mechanism. According to Referee’s opinion, for some contents we did further improvements. Specific comments 1.1. Reply: In this paper we mainly focus on that through analyzing the long time series of environment data sets for transect N in nSCS obtained during 1976-2004 to get understanding of the long term changes in the ecosystem in the nSCS, and discussing the governing factors influencing on these changes with literatures, in which we can see that many authors already did analysis of time series of river discharges and nutrient loads, and obtained clear and significant results. We just need quote their results and compare with our results. We did these in the present paper, as an example that the long-term trend in river discharges and the relation with SSS of the studied area have been described in Page 3747, Lines 26 to P.3748, L.9. 2.1. Reply: The long term series data sets were obtained by a skilled and professional oceanographic observation team of the State Oceanic Administration (SOA), China with well training, and the observations, sampling and determinations were strictly following the national specifications or criteria which are consistent with the international ones, or directly following the international standard protocols, e.g. Strickland and Parsons, 1972, as described in “Data and Methods” section. Although many modern equipments have been developed during recent 20-30 years, such as nutrient auto-analyzer, various sensors, etc, which can increase in efficiency and save manpower, but can not increase precisions mostly. For example, the readings from sensors have to be calibrated by classical methods. Furthermore, the old data were collected usually with higher frequency, and higher spatial coverage of sampling station. We are, therefore, highly confident with the quality of the data sets, even for early stage data of the observation. Description of the method of measurement and their precisions were given in SOAC (1975), NBTS (1991) and Strickland and Parsons (1972), listed in the “References”. 2.2. Reply: Transect N for long term series observation was chosen by SOA Committee of Science and Technology. The long term trends presented by three ways, i.e. the sea surface values, the water column averages and the value at 200 m would probably be instructive to reflect the upper water features, below thermocline water features and whole water column features for each parameters. Considering the topography of the study area, data for water depths $<$200 and $>$200m were analyzed, respectively for each parameter in this paper. We think it is clear and sufficient to illustrate the features of interannual changes for each parameter during the studied period. In the Fig. 8, shows the spatial–temporal distributions of the key parameter DINav (mean concentrations in the water column). 2.3. Reply: For studying on pelagic ecosystems, usually maximum 200 m water sampling depth would be sufficient, if the water depth is greater than 200 m. This is universal, and it also accords with the “Specification of Marine Investigation” No. 5 (State Oceanic Administration, China, 1975), since at the depth larger than 200 m, the properties of the waters are relatively stable and much less influenced by the upper layers and atmosphere. Therefore, correspondingly, only the physical and chemical data for less than 200 m were used. “b” in Equation 1 denotes the water depth or 200 m, if the water depth is greater than 200 m. Our calculation way for each parameter is as follows: For averaging each parameters for the transect N, we made three kinds of calculation of the average for each layer, e.g. SST, Tav and T200 for the stations located at the depth $<$ 200 m, $>$ 200 m and whole transect; for averaging water column properties, at the first, we calculated Xav of the water column for each station by using the Equation 1, then averaging them in above three kinds. This calculation way is normal. In order to make the description more clear, we added “for each station” after “for each parameter” (P.3741, L.23). 3. Reply: It is true that the variation trends of some parameters, e.g. T, S, etc., at different depth levels are distinctive, it is not appropriate obviously to plot the data of each parameter in one plot only. Although the total variation trends of other parameters, e.g. nutrients, at different depth levels are not so distinctive, the data magnitude of variation trend at different depth levels are quite distinctive (Figs. 5, 6, 7), it, therefore, is also necessary to plot the three plots for each parameter, as we did in already published papers for the Yellow

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Sea (Lin et al., JMS, 2005). As we described in “Data and Methods”, climate trend coefficients Rxt was used to assess whether there was a significant linear climate-trend in a time series (Shi et al., 1995). In fact, the significant correlation has been clearly shown in Table 1, in which most of Rxt show significant correlation, except for individual parameters, which, however, can also exhibit a certain variation trends. 3.1. Reply: In P. 3744, L. 11-14: The sentence, “The fluctuations of SST and Tav were in phase with the bottom layer temperature in the shallow water areas ($<$ 200m), while those were out of phase with T200 in the deep water areas ($>$ 200m, Table 1)” has been deleted, since, without this sentence, the results on variation trend of seawater temperature in the studied period are already clearly given. We discussed the contrasting temperature tends observed at the surface and the bottom in “Discussion” section (please see 4.1), not in “Results” section, for avoiding duplicate answers to a same question. Sorry, we can not find out the long term series data set of air temperature observed nearby coastal stations for comparison with the SST. 3.2. Reply: In a large paragraph (P.3747, L.26 to P.3748, L.17] of “Discussion” section (not in “Results” section) we described in detail that the decreasing salinity trend in surface water is attributed to increasing river discharges with many authors’ significant data. T-S relationship changing with time is a problem with 3-D, which is complicated and we afraid it is specifically appropriate for physical oceanography study, and probably beyond our studied scope. 3.3. Reply: Decreasing trend of DO in the surface water is partly due to the decrease in solubility corresponding to the increasing temperature; increasing in concentration of organic matter and respiration of microorganism induced by aggravating pollution in the coastal zone is probably another important reason. The fact that the bottom DO also decreased despite the temperature decrease, combining increase in bottom salinity are very complicated, we are preparing another paper with physical oceanographers. 3.4. Reply: We are afraid the bottom DIP trend is not against bottom temperature trend, both are decreasing trend (Figs. 2c and 5c). It is unusual to concern the correlation between DIP fluctuation and Si fluctuations. I asked several

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chemical oceanographers about this question, no one can answer it. 3.5. Reply: We have mentioned about the relation of Si fluctuation with river discharge fluctuation in “Discussion” section, e.g. “The decreasing trends in Si concentration have probably been influenced by the decrease in Si concentration in the Pearl River runoff since the 1970s (Lei et al., 2003)” (P.3749, L.10-12). 3.6. Reply: In Table 2 we listed the annually average concentration of DIN or NO3-N (the major part of DIN) in discharges of the Pearl River estuary and Qingjiang and Maolingjiang River estuary from many literatures we could find since 1980s. The increasing trend of DIN (or NO3-N) in both estuaries are very clear. The spatial and temporal specificities are indicated by the “Location of the observation” column, and the “Observation year” column of Table 2, respectively. In order to highlight the change in DIN of Pearl River estuary, those of the Qingjiang and Maolingjiang River estuary are deleted in the table. As an oceanographic paper, the major task is analyzing the responses of marine ecosystems on changes in DIN in the studied sea area, we can not describe so many land stories to pursue DIN sources, such as the consumption of nitrogen fertilizers, the River watersheds, which is very large (its drainage area being 454Œ103 km2, 6 provinces in Southern China and Northern Vietnam drain to the Pearl River system) and complicated aspect, dealing with DIN budget and its inter-annual changes. 3.7. Reply: ENSO Index has been used by many scientists in the world (Wang and Gong, 1999; Qin, 2003; Mcphaden, 2004; Levimson, 2005) as criteria for diagnosing which year El-Nino or La Nina events happen. We are afraid it is not necessary to repeat the ENSO oscillation itself. Since the topic on inter-annual variation of the Pearl River discharge and its relationship with ENSO has been achieved by many authors (Li et al., 2005; Li, 2005; Yan et al., 2006), we only need analyzing and using these authors’ results, and compared them with our data for our studied area, and we found out some important regulations that there have been excellent correspondences of our data to El-Nino and La Nina events during the same studied period (P.3751, L.1-28; P.3752, L.1-4). 3.8. Reply: We consider that “… demersal trawl catches could be partially attributed to the improvement of demersal trawl fishing techniques, and mainly to the increase in stock and production of low trophic levels, induced by the reduction in N limitation in the nSCS” (P.3752, L.17-20). It was shown in Table 6 that chlorophyll a, primary production, phytoplankton abundance, benthos biomass, etc. pronouncedly increased, which were leading to increase in fisheries resources in the second phase. In contrast to those in the Bohai Sea, where although the fishing techniques have been improved, fish catch has been still decreasing continuously. For example, in Laizhou Bay, the most important fishing area of the Bohai Sea, the demersal trawl fish catch in 1998 was 11.9% of the catch in 1992-1993, 7.3% of it in 1982, and only 3.3% of it in 1959 (Jin, 2002a, 2002b, 2002c). This probably resulted from decrease in low trophic levels, such as phytoplankton abundance and biomass, primary production, zooplankton abundance and biomass, and their biodiversity (Tang & Jin, 2002; Fei, 1991; Meng, 2002). In addition, in the East China Sea, the CPUE (catch per unit effort) for the demersal trawl fish catch have been also decreasing continuously during 2000-2005 (Lin et al., 2007). Through the comparison, we believe that the increase in the demersal trawl fish catch in the nSCS is not only due to the increasing fishing efforts, but also improving fish resources. 4.1.1. Reply: In P.3746, L.4-12, we described, “The positive increasing trends in SST and Tav in the nSCS during 1976-2004 are consistent with the increasing trends in the mean air temperature (AT) observed throughout the Northern Hemisphere (Houghton et al., 1997; Fu et al., 2006), Southern China (Chen et al., 1998; Chen et al., 1999; Zhai and Ren, 1997) and the annual means of AT and SST observed along the coast of the SCS” (He et al., 2003; Martin and Arun, 2003), and quoted 8 reference papers, including two published in “Science”. In the literatures authors provided increasing trends in air temperature with positive anomaly, particularly since early 1980s (Chen et al., 1999), which are obviously consistent with the increasing trend in SST in our paper. 4.1.2. Reply: The Referee proposed an interesting theme on calculating the contribution of river discharge to average DIN concentration in the surface layer. However, since we do not have long time series data sets of DIN in the Pearl River discharge, and its flow path and extension coverage, as well as seasonal

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and inter-annual variation, we can not calculate how much increase in average DIN concentration in the surface layer of the nSCS can be attained by the input of riverine discharge of DIN. In order to strengthen qualitative description of the influence of riverine discharge on the increase in average DIN concentration in the surface layer, a significantly relevant paper is quoted as a reference (Seitzinger et al., 2002), i.e. in P.3746, L.20, after “(SOA,2001)”, we inserted the following words: “through analysis based on DIN and PN models, combining with spatially explicit global databases, Seitzinger et al. (2002) showed that DIN input rates increased from approximately 21 Tg N y-1 in 1990 to 47 Tg N y-1 by 2050. The largest increases are predicted for Southern and Eastern Asia, associated with predicted large increases in population, increased fertilizer use to grow food to meet the dietary demands of that population, and increased industrialization. The increase in DIN in the nSCS is consistent with that observed throughout the global marginal seas. DIN from the Pearl River discharge increased by 3 times in 2002 than 1986 (He et al., 2004, Table 2), and NO3-N input from the Pearl in River Estuary was 1.7 times in 1999 than 1987 (Guan et al., 2003; Wang and Peng, 1996, Table 2). SSDIN should greatly be influenced by the increase in DIN from the river discharges”; we deleted from “The DIN in water … (L.20)” to “….have been markedly increasing” (L.23). Then changing in following sentence: “Significant inputs of DIN into the nSCS have occurred through river discharge, atmospheric dry and wet precipitation (Zhang et al., 1999) and the upwelling of the deep waters (Zhao et al., 2005)” to “In addition, significant inputs of DIN into the nSCS have also occurred through atmospheric dry and wet precipitation (Zhang et al., 1999) and the upwelling of the deep waters (Zhao et al., 2005).” (P.3746, L.23-25). 4.1.3. Reply: Yes, we accept the above opinion, the sentence “the fact that there was no uptake by phytoplankton at 200 m, and” (P.3747, L.2) has been deleted. Usually the intermediate water in the SCS is mainly located at the depth of 400-800m, and its intrusion onto the shelf slope can form upwelling, which can climb up to above 200m. Furthermore, the characters with low temperature, high salinity, high nitrate con-

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centrations and low DO at 200 m (Table 1) are typical features of upwelling and cyclonic eddies (Ning et al., 2004). As described above that the water column stratification has been increasingly strengthened due to increasing in temperature and decreasing in salinity in the surface water. The light (lower t) upper layer induced by the Pearl River plume is usually very thin (<100 m), whereas the intermediate water in the SCS is mainly located at the depth of 400-800m, it is hard to say any effects of stronger stratification on intermediate water’s behavior (Su, 2004). 4.2. Reply: In a large paragraph (P.3747, L.26 to P.3748, L.17) we described in detail that the decreasing salinity trend in surface water is attributed to increases in river discharges and Typhoon rain storms, including near the Dongsha Island in 1999 case, with many authors’ significant data. 4.2.2. Reply: The calculation result shows that 2.7% of DO decreased during the observation period was attributed to reduction of DO solubility induced by increase in SST. Although AOU can be easily calculated, its meaning is hardly understood. AOU is determined by DO saturation and in situ DO concentrations, which are not only influenced by SST, but also by other factors, such as DO consumption by decomposition of organic matter, DO release by photosynthesis of phytoplankton, etc. We do not have such data to explain the changes in AOU. 4.2.4. Reply: We have noticed that although the decreasing trend of Si data is clear, Rxt is not significant. It probably resulted from many factors governing Si budget, such as input from West Pacific through Luzon Strait, river discharges, phytoplankton uptaking, particulate Si sinking, dissolved Si regenerating, etc. Particularly, a significant proportion of total Si leaves the cycle pool to the depositary pool during its biogeochemistry cycle in the SCS (Han, 1998). The each factor has also inter-annual change. 4.4. Reply: ENSO events: In P.3751, L.7-10 “During the observation period, 9 El Nino events (1976, 1982-1983, 1986-1987, 1991, 1993, 1994, 1997, 2002 and 2004) and 4 La Nina events (1981, 1988, 1995 and 1998-1999) occurred …..”，the duration of each ENSO event was 2-6 years (Wang et al., 2003), therefore, the data coverage of the time scale and sampling frequencies are sufficient. The reason for choosing Station 4 as a representative site to study the responses of the ecosystems of the nSCS to ENSO was that “according to Takano et al. (1998) and Liao et al. (2006), there is a cyclonic eddy in the sea area around Station 4 (near Dongshan Islands) in summer. Whenever a medium and strong El Nino occurs, the summer monsoon is weak (Zhang et al., 2003; Zhu et al., 2000), which induces the cyclonic eddy to be strengthening, leading to strong upwelling, resulting in low Tav and DOav, and high Sav, nutrients and Chl a induced by phytoplankton growth. During a La Nina event, the opposite occurs.” (P.3751, L.27 to P.3752, L.4). 4.5. Reply: We believe that the “drastic changes in “Response of ecosystem” resulted mainly from the “drastic changes” in nutrients, particularly DIN (Table 3 and Fig. 8). The comparison of ecosystem data between the two phases listed in Table 6 is corresponding to Table 3 and the feature of the spatial–temporal distributions of the DINav (mean concentrations in the water column) in Fig. 8. The ecosystem data listed in Table 6 were originally quoted from various literatures widely published in many journals we could find, showing the average values of many authors’ observation results. Most of these data are not originally issued by the present author. And for the question “As mentioned earlier (Comment 3.8), the fish catch must be strongly affected by fishing efforts, but little light.”, we already answered in Comment 3.8. Additional references: Chen, T., Qian, G., Zeng, X.: Trends of the changes in air temperature in Hong Kong , Macao and Guangzhou during 20th century. Studies and Developments in the South China Sea, 1, 12-17, 1999. Fei, Z., Mao, X., Zhu, M.: Studies on the biological productivity  chlorophyll a, primary production, and the exploitation potential of fisheries resources in the Bohai Sea. Marine Fisheries Research, 17, 55-70, 1991 (in Chinese). Jin, X.: Feeding and competition of juvenile fish in Laizhou Bay. In: Su, J., Tang, Q. (Eds.), Study on Ecosystem Dynamics in China Sea, II, Processes of the Bohai Sea Ecosystem Dynamics. China Science Press, Beijing, pp. 230-233, 2002a (in Chinese). Jin, X.: Community structure and biological productivity. In: Su, J., Tang, Q. (Eds.), Study on Ecosystem Dynamics in China Sea, II, Processes of the Bohai Sea Ecosystem Dynamics. China Science Press, Beijing, pp. 313-354, 2002b (in Chinese). Jin, X.: Influence of fishing on biological community

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