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ANALYSIS OF SURVEY DATA OF *NEMIPTERUS JAPONICUS* FOUND ALONG THE WEST COAST OF INDIA

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ABSTRACT

An attempt is made in this report to evaluate the spatial distribution of *Nemipterus japonicus*, found along the west coast of India with the aim of improving understanding of existing patterns of distribution. The main objective of this study is to understand the variability in the survey data collected over the last 10 years as well as to make use of the GLM in R-package to quantify some of the explanatory variables accounting for explained variability such as year, month, time, space, towing speed, depth etc. on the response variable, that is on the expected catch of the fish. The more comprehensive method (GLM) used in the study would provide more reliable estimates of catch rates than the traditional averaging method. Environmental factors such as temperature, salinity, and oxygen are basically responsible for spatial and temporal distribution of the fish. The inclusion of these factors in the GLM analysis would further enhance the reliability of the estimates. This should be a concern in future surveys.

ACRONYMES

CMFRI - Central Marine Fisheries Research Institute.
CPUE - Catch per Unit Effort.
EEZ - Exclusive Economic Zone
FSI - Fishery Survey of India
GLMs - Generalised Linear Models
ID - Identification
MRI - Marine Research Institute
MoA - Ministry of Agriculture
MSY - Maximum Sustainable Yield
MSE - Maximum Sustainable Economic Yield
SST - Sea Surface Temperature

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1 INTRODUCTION

1.1 Background

The subcontinent of India lies in south Asia, between Pakistan, China and Nepal. India is has a 2.02 million km^2 Exclusive Economic Zone (EEZ) along the coast line of 8129 km and 0.5 million km^2 of continental shelf with a catchable annual fishery potential of 3.9 million tonnes (MoA), occupying a very important strategic position in the Indian Ocean (Figure1).

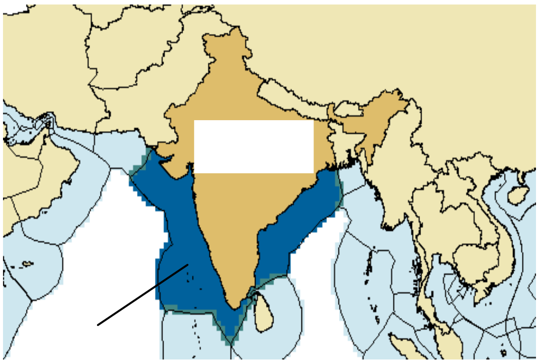

Figure 1: The Exclusive Economic Zone of India.

The estimates of annual marine productions during the period 1992 to 2005 from the Indian coast show that they fluctuate between 2.4 and 2.8 million tonnes (MOA 2006). The production from inshore waters of less than 50 m depth reached the estimated potential yield of 2.2 million tonnes and scope for further increase is limited. Monitoring of the landing centres showed that catch rates are declining as the number of fishers and the number and efficiency of fishing vessels has substantially increased. The density of fishers per km^2 in the past four decades has increased from 3.6 to 8.5. This excess effort has resulted in overfishing of the stock and lower economic income from the fisheries (Vivekanandan *et al.* 2003). *Nemipterus japonicus* production in India varied from 1998 to 2004 with an average of 90,000 to 110,000 tonnes, forming of about 3% the total marine fish landings of the west coast of the country (CMFRI REPORT 1996 - 2006) (Figure 2).

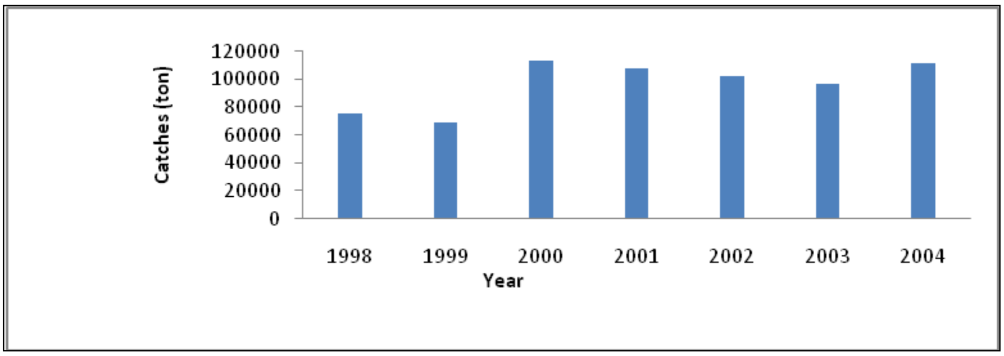

Figure 2: Catch landings of *N. japonicus* around the western coast of India between 1998 and 2004.

1.2 Importance of survey

The main purpose of the surveys carried out in the Indian EEZ through the Fishery Survey of India's fishing fleet is to assess the abundance of the stock and to gather biological information on the resources. The advantage that scientific surveys have over catch based techniques such as commercial CPUE abundance index for any species for assessing the stock is that the uncertainty associated with survey estimates of population characteristics can be quantified, whereas it is difficult to measure uncertainties associated with commercial CPUE abundance. With the adoption of the 200 nautical miles legal regime sea around the country, India acquired sovereign rights with a responsibility to explore, utilise and manage the maritime living resources in the 2.02 million km^2 EEZ.

The FSI is primarily responsible for conducting surveys and assessment and monitoring marine fishery resources in the Indian EEZ and adjoining high seas for their optimum utilisation and sustainable development. A fishing fleet is deployed for fishery resources surveying and monitoring. The FSI performs trawl surveys all along the Indian EEZ. The FSI trawl survey geo-referenced data have been the only available source of data to evaluate the spatial distribution and to estimate spatial stock distribution and abundance of fishery resources in the Indian EEZ.

1.3 Selection of the species

N. japonicus is a demersal resource and is caught invariably in almost all trawls, seasons, and areas. The main reason for selecting this species is that it is known for its wide distribution along the west coast and variability in catch at seasons and space. Also, the catches from fish populations managed within the judicial limit of Indian EEZ have been fluctuating substantially over the last decades. In many places the catch declined drastically, creating serious economical, social and ecological problems and accurate assessment of biomass indices are becoming crucial for sustainable harvest of the resource (Vivekanandan *et al.* 2003).

N. japonicus grows to a maximum size of 28 cm total length (excluding filament), the common size of the fish reported in the survey data is 15-20 cm. It is widely distributed throughout the Indian Ocean and is abundant in coastal waters but caught in depths of more than 200 m. It is mainly found in mud or sand bottoms, usually in schools. *N. japonicus* is a low priced food fish and a good source of food for poor people in India.

This fish is mostly caught in trawls all along the Indian EEZ. This fish is fast growing and its life span as reported in the literature is around 3 -4 years in the Indian waters. The growth parameters of *N. japonicus* exploited from the Arabian Sea off Karntaka are estimated as L_∞= 33.0 cm and k= 1.0 yr^{-1}.The approach using the data after correction of selection gives better estimates when compared with the estimates from uncorrected data. The M (natural mortality) was 1.87 and the mean Z (total mortality) value was 5.65 with the exploitation rate of 0.68. The virtual population analysis reveals that the maximum fishing mortality occurs at 25.5 cm. The Thompson and Bell analysis shows that the present yield of 3,416 tonnes can be increased to the MSY level of 3,501 tonnes by increasing the effort by 10% whereas MSE would be at 80% of the present fishing effort (Zacharia 1998).

1.4 Objectives of the study

In this report, an attempt is made to evaluate the spatial distribution of *N. japonicus* along the west coast of India with the aim of improving understanding of existing patterns of distribution that is a prerequisite for rational and sustainable management, which has to be based on sound scientific findings. The main objectives of this study are:

i) to quantify some of the explanatory variables accounting for explained variability such as year, month, time, space, depth etc. on the response variable, that is on the expected catch of this fish.

ii) to understand the variability in the survey catch collected from the FSI's vessels over the past 10 years.

2 LITERATURE REVIEW

Although nonlinearity of fish and fisheries processes is a distinctive feature of models in fisheries research, linear modelling techniques have a long and distinguished history in quantitative fisheries science (e.g. Beverton and Holt 1957, Ricker 1973, 1975). Simple linear regression is appropriate for quantifying the nonlinear relationship between weight and length after making a logarithmic transformation of these variables. In the latter part of the 1970s, multiple linear regression methods (e.g. Schnute 1977) were realised. Multiple linear techniques are frequently applied in knowing the association among fish abundance, biological variables, and environmental variables. In addition to linearity, multiple linear regressions also assume normally distributed error terms and independent observations. For general purpose use in quantitative fisheries modelling, these assumptions are provisional.

There is a need for a methodology that can model data that are not normally distributed, including data in the form of counts or proportions. Generalised linear models (GLMs) have been developed in the field of statistics in recent years and are now very frequently used in quantitative fisheries modelling, because GLMs can be used when variance is not constant, and/or when the errors are not normally distributed. Many response variables invariably suffer from these two contraventions of the standard assumptions and GLMs are excellent at dealing with them. Specifically, these models do well even when the response variable is i) count data expressed as proportions, ii) count data that are not proportions, iii) binary response variables, iv) data on time-to-death where the variance increases faster than linearly with the mean. These methods have become more assessable to the general fisheries community through the availability of user-friendly statistics packages, such as R, Splus and SAS. These models can be applied rather easily, the need for critical evaluation of assumptions and diagnostics remains as important as ever.

Baranov may have been the first to use CPUE in fisheries (Dunn *et al.* 2000). Allen and Punsley (1984) and Westrheim and Foucher (1985) provided a brief history of the use and methods of standardisation of CPUE in fisheries, which started in the mid 1950s. Mathematically, standardisation is a simple process involving the comparison of CPUE data from multiple sources by accounting for various factor effects through the use of a general linear model (GLM) (Hilborn and Walter1992:209-210, Quinn and Deriso 1999:18-23.

Maunder and Punt (2004), reviewed the current state of the art in the methods for standardisation of catch and effort data, drawing on the major estimation approaches being applied, the methods for dealing with zero observations, selection criteria of appropriate explanatory variables, and the use of standardised catch data in conducting stock assessments. In this paper, a review has been focused on the methods used most frequently for standardised catch and effort data, specifically those that can be implemented using such popular statistical packages as Splus and SAS and concluding in the paper that many methods, although they are now available to standardise catch and effort data, little effort has been directed towards identifying the most appropriate methods for specific instances. Some simulation work (e.g. Porch and Scott 1994, Maunder 2001, Campbell 2004) has been undertaken, but additional work along these lines is clearly a high priority for the future.

Battaile and Quinn II (2004) used the GLM to standardise Catch per Unit Effort (CPUE) data for Alaska walleye pellock (*Theragra chalacogramma*) from the Bearing Sea fleet for the years 1995-1999. Data were stratified temporally by year, season and spatially by area using either Alaska Department of Fish and Game (ADF&G) or National Marine Fisheries Service (NMFS) reporting areas. Four factors were used: vessel identification (ID) number, vessel speed, percentage of Pollock by weight in the haul (a measure of targeting), and whether most of the haul took place before or after sunset. GLM models could explain from 31-48% of the total sums of the squares. Whereas the model sum of squares over areas for a particular year and season ranged from 36-49% of the total sum of the squares, vessel ID accounted for most of the explained variability (26-40%). Averaged over years and seasons, the model accounted for 42.4% of variability in lnCPUE, of which 29.7% was due to vessel ID. This study revealed that there is an increase in CPUE with the percentage of Pollock caught in a haul. Given the same amount of time hauled and a total haul weight, a vessel with a great percentage of Pollock in the catch would have a larger CPUE.

Brynjarsdottir and Stefansson (2004) used the GLM for the catch data from Icelandic ground fish surveys. There an attempt was made to evaluate the effects of environmental variables on the expected cod catch and to distinguish between the gamma and log-normal distributions for the error structure. Only the positive part of a delta–gamma or delta-log-normal distribution is used for evaluation. The distributions are compared via a Kolmogorov-Smirnov goodness of fit test. Polynomials are used to describe the relationship between each environmental variable and the cod catch and their effects are tested within the GLM framework (a continuous model). The environmental variables could explain 27% of the variation, and when the polynomial in latitude, longitude and year is added, these terms together explain 43.9% of variation which is marginally more than the latitude, longitude and year polynomial alone (41.1%). The bottom and surface temperatures could explain 20.6% and 18.0% of the total variation when performed separately. The effect of surface temperature on the location of cod is being taken by bottom temperature and depth, when both are added in the model, the surface temperature could explain an additional variance, which is only 1.6% but found to be highly significant and may be an indication of the behaviour of pelagic prey such as capelin. Advantages and disadvantages of this model are also discussed in this paper. Finally in this paper an attempt is made to locate temperature fronts in the ocean by estimating the temperature gradient vector at each data point. There is no doubt that water temperature (and its fluctuations) is the environmental parameter mostly used in investigations concerning relationships between the environment and fish behaviour and abundance. Temperature is also a useful indicator of important ocean processes (such as coastal upwelling, advection, mesoscale dynamics features including fronts and eddies, etc.). The advantages of undertaking such study can be summarised in the following three items: (i) saving of fuel while seeking fishes, (ii) lesser expenses with the crew as a consequences of spending less days at sea, (iii) lower costs with ship maintenance because of less ship time needed and safety at sea.

The FSI's database on sea surface temperature (SST) and tuna abundance have enormous potential to begin to do something relating to this kind of study in collaboration with the MRI in Iceland in the future which would be of great importance to predict commercially fishable aggregations of fish in space and time around the Indian EEZ.

Construction of annual indices of stock assessment based on catch and effort data remains crucial to many fisheries assessments. In fact, use of advanced statistical methods has helped catch rates in standardising against many explanatory variables, additional challenges for constructing reliable indices of stock assessment are emerging because of changing spatial characteristics of most fisheries data sets.

Campbell (2004) made an attempt to illustrate the manner in which biases could enter into the estimates of annual stock abundance due to the fishery undergoing changes in spatial allocation of fishing effort. Potential biases arising from unequal and changing nature of the spatial distribution of fishing effort are examined and illustrated through the analysis of simulated data. In this paper as discussed that commercial catch and effort data continue to be relied upon to estimate annual indices of stock abundance in absence of fishery independent data. GLMs and other statistical techniques undoubtedly have improved ability to standardise such data but problems still persist. While some of these problems are linked to the choice of most appropriate model and error structure and the absence of data on the factors which are likely to be most essential and influential on catch rate, there are more general problems of deciding that catch rate data from the changing nature of the spatial distribution of fishing effort can, in fact, reflect stock abundance. The analyses carried out in this paper have shown the manner in which biases can enter into the estimates of annual stock abundance from the unbalanced and changing spatial distribution of fishing effort. Finally, this paper has focused on the problems with the construction of indices of the stock abundance based on the analysis of the commercial catch and effort data in a spatially varying fishery with an uncertain stock and effort dynamics, interpretation of commercial catch rates as indices of stock abundance depend on many factors. Many of these factors are well known and could bring improvements in the operational and technological aspects of fishery, changes in environmental and oceanographic conditions, together with the influence of economic and management related decisions, all these factors may change catch ability and availability over time. Attempts need to be made to assimilate and document these processes and improve understanding of how these factors influence catch rates, which is essential and remains a high priority for fisheries research.

CPUE data are often the source of obtaining a relative index of abundance of a fish stock by standardising nominal CPUE using various statistical methods. Fundamental to most of the methods applied for standardising, the CPUE assumes the independence of the observed CPUEs. This assumption does not hold good for a fish population due to their spatial autocorrelation.

Nishida and Chen (2004) incorporated spatial autocorrelation into the standard general linear model (GLM) to overcome this problem. To reflect more effectively the vertical distribution of tuna, an attempt is also made in this paper to integrate Habitat-based models (HBM) into the standard GLM in recent CPUE standardisations. Both the standard GLM and spatial GLM (with or without HBM) were fitted as a case study to the yellow fin tuna CPUE data of Japanese long line fisheries in the Indian Ocean. Four distance models (Gaussian, exponential, linear, and spherical) were examined for spatial auto correlation. As concluded in paper, the spatial GLM always produced the best goodness of fit to the data and gave more realistic estimates of the variances of the parameters and that HBM-based GLMs always produced better goodness-of fit to the data than those without. The paper concluded that coupling the spatial approach with GLMs is just not enough. Many common statistical methods, such as general additive models, regression trees, and neural networks can be also made spatially. Simulation may be an effective method for evaluating the degree of spatial dependency and spatial structured CPUE data. As it is hard to convince in catch and effort analysis what subset of data is relevant to the analysis.

Stephens and MacCall (2004) have proposed an objective approach to sub-setting trip records on catch and effort data when fishing locations are unknown; species composition taken on a fishing trip is used to infer if that trip’s fishing effort occurred in the habitat where the target species is likely to occur. In this paper a logistic regression of multiple species presence – absence information is used to predict the probability that the target species would be present. In the objective approach for sub-setting the trip records, a critical value of probability that best predicts target species presence and absence in the data set forms an objective basis. The approach is tested by applying it to the data set where individual fishing locations are known and showed that the method is an effective substitute for information on fishing location. In this approach, authors are restricted to sub-setting analysis to categorical presence and absence data. Authors prefer the use of presence and absence data because they should be less influenced by trends in abundance of other species. This method is especially valuable in that it is reproducible by independent analysts. It also reduces the need for ad hoc decisions in stock assessments and contributes to improved consistency among such assessments.

Catch and effort databases often include high proportions of records in which the catch is zero, even though effort is recorded to be non-zero. This is particularly the case for less abundant species and for by catch species. Unfortunately, these species are often those for which a standardised catch rate index is the most important (or the only) source of data on the changes in abundance (Ortiz and Arocha 2004). The presence of many zeros can invalidate the assumptions of the analysis and jeopardise the integrity of the inferences if not properly modelled (Lambert 1992). The zeros can also lead to computational difficulties. For example, zero catches cause computational problems for the standard log-linear approach because the natural logarithm of zero is undefined.

Stefansson (1996) has described a method for the analysis of ground fish survey data accommodating zero and non-zero values into a single model. This model modifies the delta-distribution approach which takes into account that survey data often contain a large proportion of zero values and that the non-zero values form a log –normal distribution rather than a normal distribution and are fitted into the GLM framework and use maximum likelihood to estimate parameters. No prior assumptions of homogeneity are made for the structure of zero or non zero values. The method is primarily applicable to fixed–stations designs but could be extended to other designs. The model provides an analysis technique which lessens the problem of survey data often containing a large proportion of zero values. This includes some of the issues involving the definition of an appropriate area for the analysis and those related to log-transforming values which can be arbitrarily close to zero. The approach considered is based on a model which has considerable intuitive appeal in that it includes most of the concerns usually raised in the analysis of ground fish survey data. Furthermore, the approach can accommodate spatial and temporal variability in an explicit model. The model has considerable potential for the general analysis of ground fish survey data, since it can incorporate several relevant properties of fish distributions, including changes in density and range. The usual qualities of GLMs, specifically the potentials for incorporating, estimating, and testing effects such as diurnal variations, are also available. The author suggested that the joint consideration of the coarse –scale spatial distribution modelled here and the finer –scale effects expressed in the *intra* haul correlation which is not accounted for in the paper, is of major interest and needs to be considered further.

The catch data for *N. japonicus* from the west coast of India is put in to GLMs (McCullaugh and Nelder 1989). The main goal is to find other associated variables that affect the expected catch of this species. This technique is most commonly applied to standardising CPUE data. CPUE from commercial fisheries has been used to derive indices of relative abundance or to estimate fishing effort for many world fisheries (Robson 1966, Large 1992, Stefansson 1996, and Goñi *et al.* 1999). However, the use of catch rates in constructing abundance indices or estimating fishing effort requires standardisation to take into account changes in the ability to catch fish, and fleet composition, and to adjust catch rates such as year, month, boat type, landing port or abundance of other target species in the catch (Hilborn and Walter 1992).

3 MATERIAL AND METHODS

Catch data for *N. japonicus* collected from FSI's vessels are analysed in this report using mainly GLMs. The GLM technique has been used to estimate the effective extents of various factors because GLM allows identification of the factors that influence catch rates as well as computation of standardised catch rates, represented by the year effect factor after taking into account the effects of other factors, which are used in many stock assessment methods. The analysis presented here is partly done in R, a free statistical software package (http://www.r-project.org) and partly in S-PLUS (Venables and Ripely 2002). R is available from the Comprehensive R Archive Network (http://cran.r-project.org).

Data used in the present study were collected from seven vessels of the Fishery Survey of India in the years 1996-2006 along the west coast of India, a total of 7,102 sampling stations.

3.1 Survey design and implementation

The survey area is defined as the continental shelf along the west coast of India to 200 m depth contour line from 6ºN to 23ºN. Two vessels placed at Kochi (Kerela) covered the area from 6º-12ºN, two vessels placed at Mormugoa (Karnataka) surveyed the area from 12º-16ºN and the three vessels at Mumbai (Maharashtra) covered the area from 16º-23ºN. Half of the stations are planned to be taken in the depth range of 30-50 m, 20 stations in 50-100 m depth and 10 stations in waters deeper than 100 m.

In the first week of each month stations are selected randomly within each depth range and plotted on navigation charts to be used by ship's officers. The areas of untrawlable bottom, when encountered during the voyage, are noted and are excluded from the survey area.

A standard gear of head rope with 40 mm mesh size is used, towed 3-4 nautical miles for 1.5 hours.

3.2 Sampling catches at sea

The distribution of 5916 sampling stations over the space is shown in Figure 3.

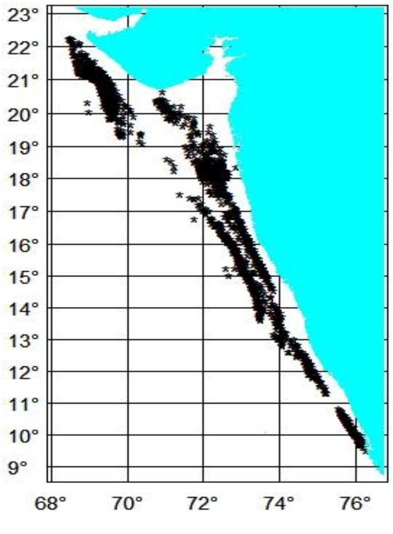

Figure 3: Sampling stations between 1996 and 2006.

The basic data collected include total weight and a length frequency sample of each individual species in the catch. The size of the proper sampling procedures varies with circumstances but nearly always involves sorting major species from the catch prior to taking measurements.

The total catch of small uniform –size fishes is often recorded simply as the baskets of unsorted fish, and a small random sample of baskets are then weighed, sorted by species, and sampled for length frequency. The principal requirement is to use a sampling procedure which involves an unbiased sample of catch and careful record of the exact size and nature of the sample so the proper expansion factors can be calculated.

3.3 Recording data at sea

Careful record-keeping at sea is as important as using care in standard trawling methods and proper catch sampling techniques. A trawl log format has been designed by the scientists of Fishery Survey of India, Mumbai India (Appendix1).

3.4 Implementation

Due to mechanical problems of survey vessels, weather conditions, financial constraints etc. the survey has not been conducted according to design.

4 INITIAL ANALYSIS

4.1 Spatial and temporal distribution of stations

In order to analyse the spatial and temporal coverage of survey stations, a map was made showing catch per tow by year, month and area. It can be seen on those maps (Appendix 2) that sampling distribution shows considerable spatial and temporal heterogeneity. It is evident from those maps that the distributional area of *N. japonicus* is not covered in the surveys within a reasonable timeframe within a year. Obviously an annual abundance index based on simple averages of catch per tow or any kind of stratified mean index will not be informative as factors such as non uneven distribution of the population in time and space, possible migration between survey areas, recruitment to the survey biomass and catches taken during the year would seriously bias an annual abundance index based on such an approach. The GLM technique seems to be a more appropriate tool to use for estimation of yearly abundance index based on the present data set as that technique allows for taking into account the affects of various factors on catch rates and will therefore be used in the present study.

4.2 Number of stations by months and years

The annual numbers of survey stations (Figure 4) shows that survey effort is unevenly distributed over space and years. The survey effort is relatively lower in the initial years of the survey but gradually shows an upward trend until the year 2006.

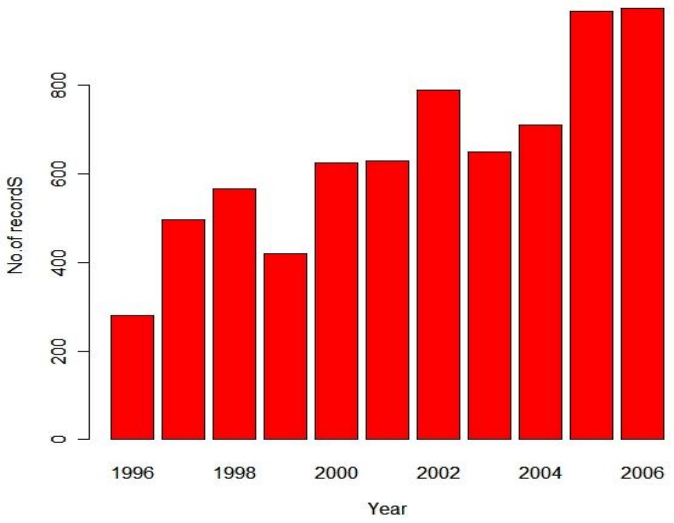

Figure 4: Number of records available between 1996 and 2006.

The number of sampling stations surveyed during the period 1996-2006 shows that June, July and August are the three months which have an exceptionally low number of records. This may be because of the onset of the south-west monsoon in India and FSI's vessels usually undergo repairs during this period. (Figure 5).

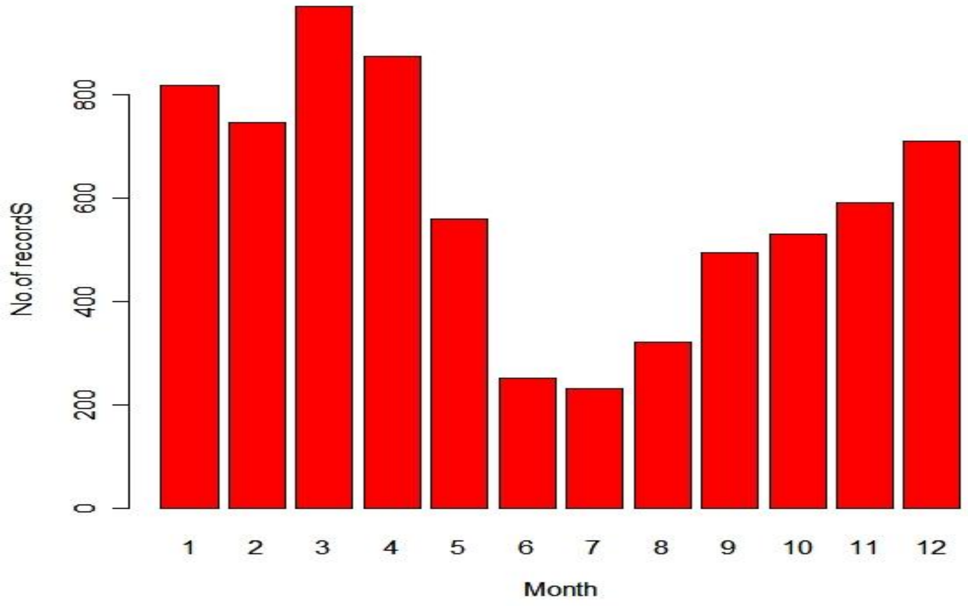

Figure 5: Number of records available by month for the western Indian Ocean survey between 1996 and 2006.

4.3 Towing distance

The towing distance is not recorded during the survey but can be calculated either by using geographical positions of tows or by using towing speed and time. Noticeably a difference is seen between observed speed and calculated towing speed. To make a decision on reasonable speed for standardisation of catch, an attempt is made to calculate speed, using the observed speed of 3 and 4 knots often used in towing. This attempt reveals that in more than 92% instances the calculated speed lies within 2-6 knots. It was, therefore, decided to use the distance based on registered towing speed and time rather than towing distance based on positions of tows to standardise the catch rates Figure 6.

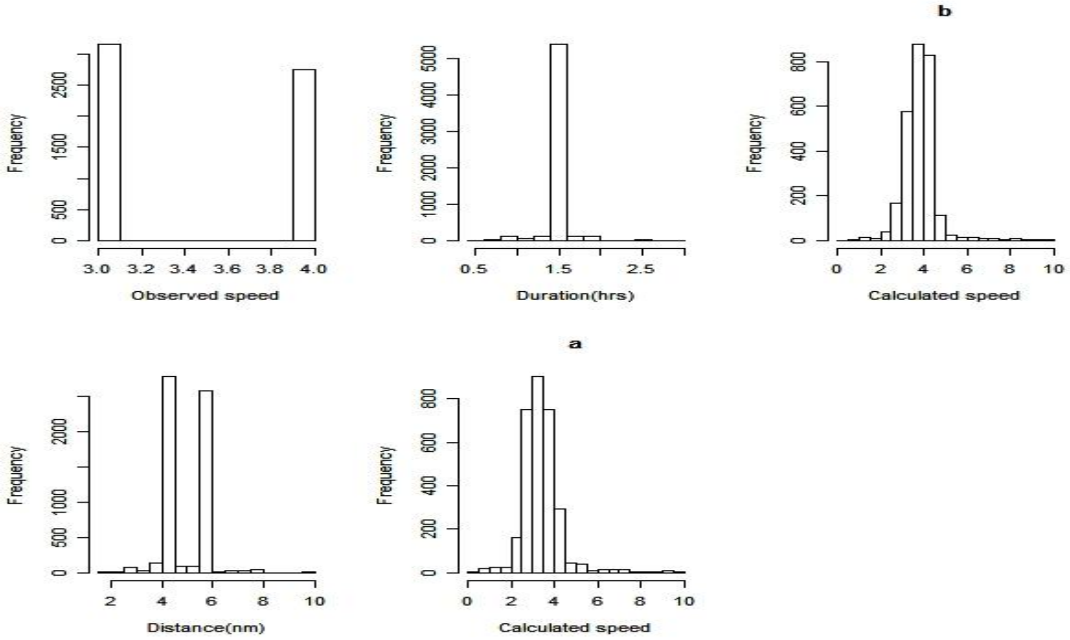

Figure 6: Observed speed, duration, towing distances, calculated speed (when observed speed is 3 and 4 knots).

4.4 Catch rate by depth

The mean catch of *N. japonicus* is invariably higher in all the years between 1996 and 2006 in the deeper waters in compared to shallow waters, i.e.0-50 m. The catch rate of the species declined marginally in some of the years. In 1998, the catch rate is low in the depth strata of 0-50 m and 50-100 m. The low catch rate is reported in the depth strata of 0-50m and 100-150 m in recent years (Figure 7).

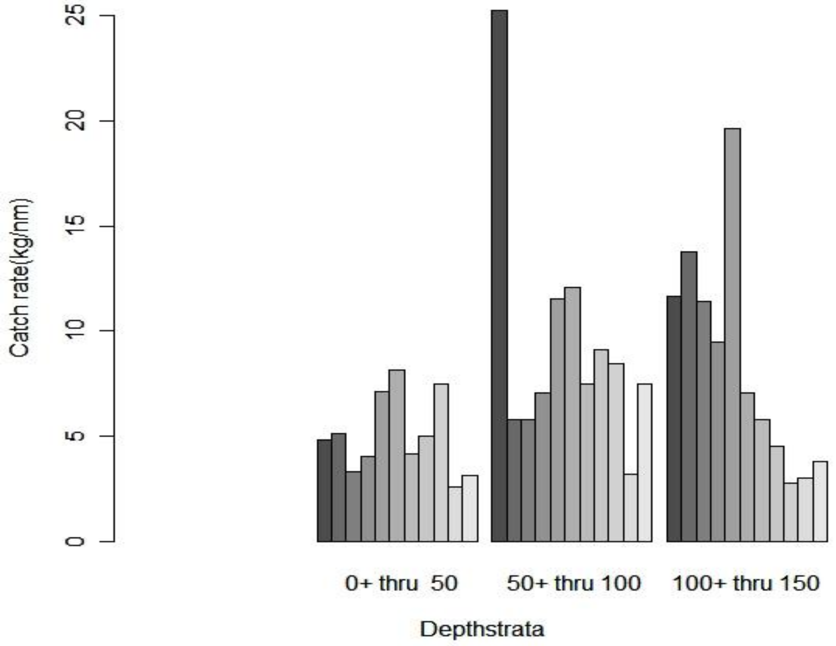

Figure 7: Depth-wise and year-wise mean catches of *N. japonicus* based on the data collected between 1996 and 2006 (columns represent each year).

In general the mean catch (inclusive of all the species) increased from the year 1996 until the year 2002 and started declining until 2006 in the inshore waters (0-50 m), where the commercial fishing is usually done. In most of the years the catch rate obtained in the deeper waters (100-200 m) is relatively higher than the catch rate of the inshore waters. This may be because the effort expended are relatively less in the deeper waters, which may be resulting in higher standard deviation of the catch per unit area (CPUA) and is often found to be proportional to CPUA (Figure 8).

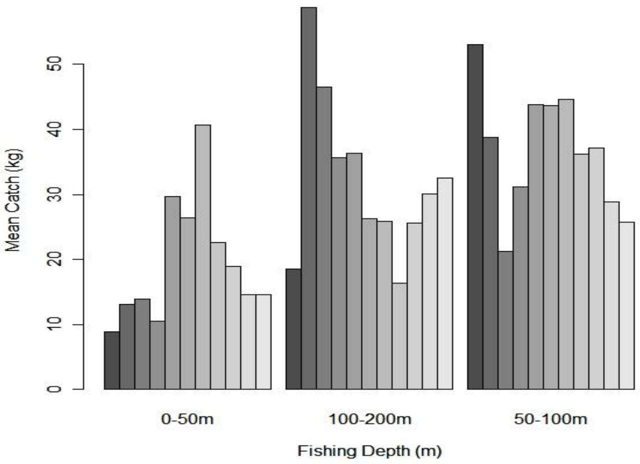

Figure 8: Depth-wise and year-wise mean catches (kg/nm) for all the species based on the data collected between 1996 and 2006 (columns represent each year).

4.5 Catch rate by latitude

The catch rate of *N. japonicus* was found to be very high in the 4th quarter of the latitude strata 6 -8°N. In all the other strata the catch rate of this species was found to be relatively very low. The 3rd quarter is found to be more abundant in all the strata except the strata of 6-8°N (Figure 9).

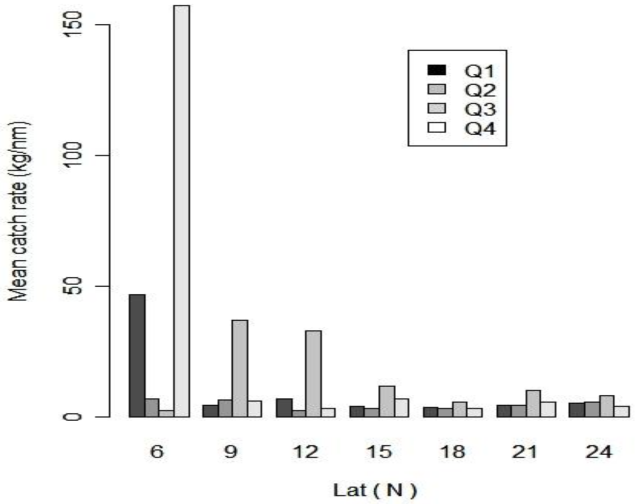

Figure 9: The latitude-wise and quarter-wise standardised catches of *N. japonicus* based on the data collected between 1996 and 2006.

The catch rate of *N. japonicus* was found to be a lot higher in the latitude strata 6-8°N than in other northerly latitudes. Deeper water appears to be more productive in northern latitudes (Figure 10).

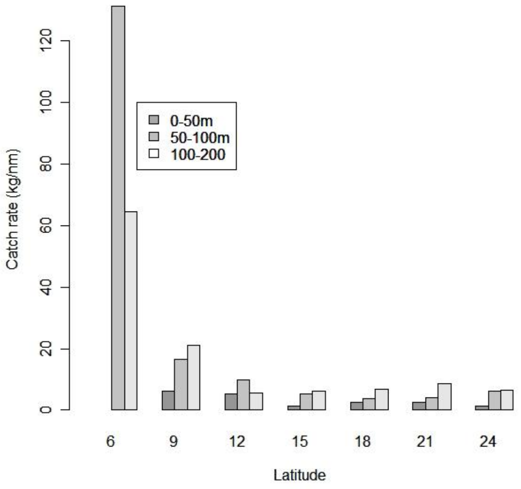

Figure 10: The latitude-wise and depth-wise catches of *N. japonicus* based on the data collected between 1996 and 2006.

4.6 Diurnal variation in catch rate

The mean catch of all the species in the shallow waters i.e. up to 50 m depth is registered relatively low during day time fishing (Figure 11). The mean catch of all the species is marginally higher in the deeper waters than in shallow waters during morning hours i.e. 0600-0900 hrs. The depth range 50-100 m contributes more than the other depths during 0600-0900 hrs.

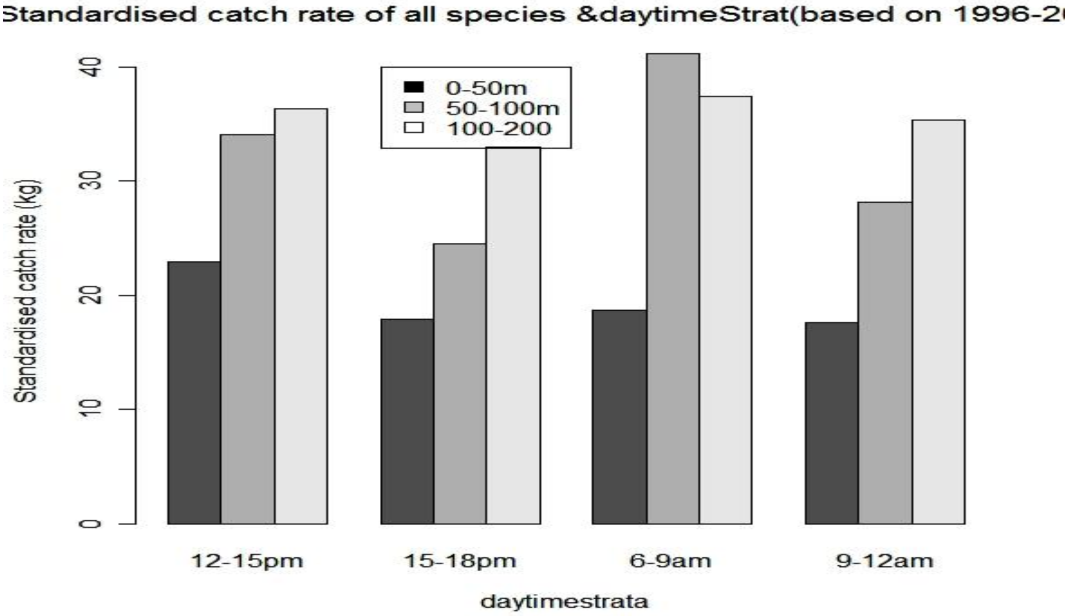

Figure 11: Fishing time (day time strata) and depth-wise mean catches (kg/nm) based on the data collected for all the species between 1996 and 2006.

The mean catch of *N. japonicus* in 0-50 m depth is low compared to other depth zones in day time fishing. The depth zones 50-100 m and 100-200 m contribute almost equal catch in time fishing (Figure 12).

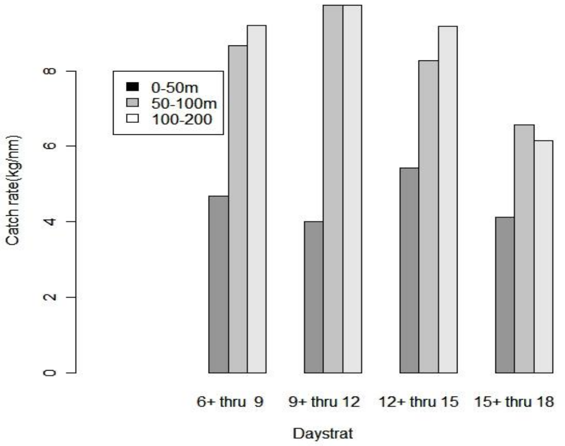

Figure 12: Fishing time (day time strata) and depth-wise mean catches (kg/nm) based on the data collected for *N. japonicus* between 1996 and 2006.

4.7 Catch rate by quarters

The catch rates for all the species during the years 1996-2006 show the variations within each year and also skews within each year. There is a wider range of values in the 50%- 75% quartile than in the 25%-50% quartile for almost all the years between 1996 and 2006. The medians for the years 1997 and 2002 are relatively higher than the medians of the other years but there is little to suggest that any of the years are significantly different from one another (Figure 13).

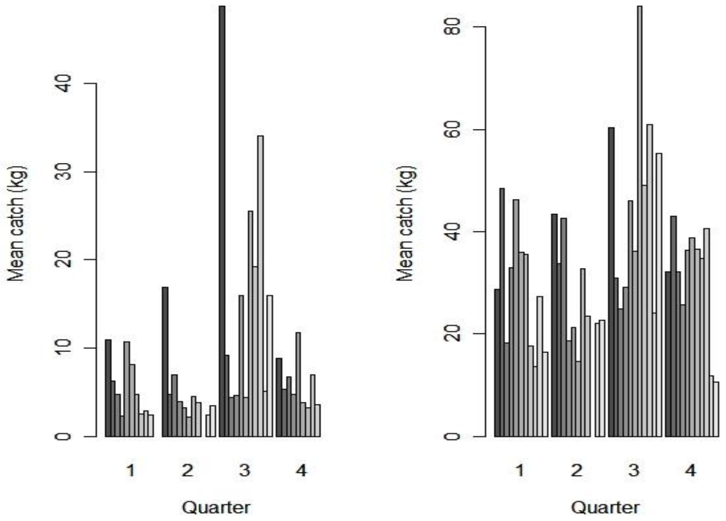

Figure 13: Quarter-wise mean catches (kg/nm) of *N. japonicus* and all species based on the data collected between 1996 and 2006.

5 ELIMINATION OF ERRORS AND INCORRECT REGISTRATION IN THE DATASET

The following steps were performed in the clean up procedure, enabling us to arrive at a clean data set, which could be finally used in GLM; several records in datasets were identified where geographic positions of hauls were clearly outside the area. The study area was defined as between latitudes 6 and 23°N, the coastal line and the 200 m depth contour. A total of 151 sampling stations of were found outside this area and were excluded from the analysis. 854 stations were excluded because of missing values and an additional 34 because of various kinds of wrong registrations. After filtering out data a final dataset of 5916 sampling stations was used for further analysis. The year wise and month wise distribution of sampling stations of the final data set are shown in Table 1.

Table 1: Year-wise and month-wise distribution of sampling stations of final data set.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1996	33	19	22	7	20	7	7	3	17	33	2	38
1997	18	1	34	49	21	4	3	32	24	84	39	63
1998	61	45	78	59	60	3	-	14	3	15	40	19
1999	19	-	33	40	20	5	-	2	31	43	38	47
2000	27	81	50	75	12	40	18	10	48	44	36	59
2001	64	59	76	50	18	1	-	34	38	34	42	42
2002	100	89	113	97	81	20	17	10	41	35	37	71
2003	43	58	80	101	67	22	27	55	27	32	57	57
2004	77	94	119	71	66	13	69	4	20	19	62	72
2005	153	127	139	142	45	27	19	10	42	31	47	72
2006	104	91	127	103	78	56	9	29	43	33	78	75
Total	699	664	871	794	488	198	169	203	334	403	478	615

5.1

5.2 Model

In order to analyse the variability in the standardised catch for *N. japonicus* with factors such as space strata, year, month, depth, speed and day times strata. GLMs (McCullagh and Nelder 1989, Chambers and Hastie 1992 were used, applying the corresponding subroutine of R & S-plus 2000 package. Vessel's ID is a unique vessel number assigned by FSI. Exploratory data analysis carried out at many instances revealed that among-vessel and gear differences were insignificant, hence, vessel ID and gear ID were not used as factors in the present study.

The GLM used in the report is

1. Model<-glm(log(y)~factor(strata)+factor(year)+factor(month))+factor(depth)+factor(daytime)+factor(speed), where y is the expected catch for respective the year factor (strata) = (round(lat/3)*3), factor(month) = (Jan-March ,April-June, July-Sept, Oct-Dec)

5.3 GLM analysis

The frequency distribution of the *N. japonicus* catch rates was skewed, having a large number of zero values and a heavy tail. The background information on zero values was also not available to substantiate its absence only when total catch was zero. There was not a single record showing the absence of this species when the total catch was non zero. The presence of a large number of zero values only in the nil catch hauls may not be very significant in the computation strategy. When zero values were eliminated, the data found to be close to lognormal distribution, which implies that a lognormal or gamma distribution may be appropriate for positive values (Stefansson 1996). Therefore, the lognormal model is used for this species in the present study. One of the main purposes of GLM analysis of catch rates is to provide year effects. For a main effect model, year effects can be derived from the coefficients by setting “options (contrasts=c (“contr. treatment”, “contr.poly”)) in the R package. However, the year effects could also be extracted with special care, if the model contains interaction term with year. The common approach of extracting the year effect alone from a log-linear model can be replaced by an integral of the fitted model over the entire scale under consideration. This approach, however, yields catch rate indices that are equivalent to the year effects when the model contains no interaction terms (Stefansson 1996). Therefore, only the main effect model was used to estimate the variation of the catch rates over year in this study. Model drop1 was used to compute all the single terms in the scope argument that can be added to or dropped from the model. Model was fitted and computed a table of the changes in fit.

All the variables, latitude strata (space), years, quarters (seasons), depth strata (fishing depth) and towing speed contributed significantly to the model (Table 2) indicating significant variation in the catch rates with latitude strata (area), years, quarters (seasons), depth strata (fishing depth), and speed (towing speed) for the species *N. japonicus* collected from the FSI’s vessels during the period 1996-2006. The analysis of deviance for log normal based GLM model fitted to *N. japonicus* catch rates shows that all main effects except day time strata (fishing time) are highly significant (p<.0001). The insignificance of the day time strata indicates that fish does not exhibit any diurnal variations.

Table 2: The analysis of deviance for log normal based GLM model fitted**.**

None	DF	Deviance	AIC	F-VALUE	Pr (F)	Significance
		10739	20366			
FACTOR (LATITUDE STRATA OF 3º N)	6	11578	20800	76.04	0.0001	***
FACTOR (YEAR)	10	11330	20666	32.69	0.0001	***
FACTOR (QUARTERS)	3	11190	20604	82.49	0.0001	***
FACTOR (DEPTHSTRATA)	3	10955	20478	39.53	0.0001	***
FACTOR (SPEED STRATA)	1	10971	20497	127.4	0.0001	***
	***	Significant				

The annual variation in catch rates, using the model with six variables is obtained by the anti-logarithm of the estimates of ln(CPUE). The annual variation of catch rates is then plotted directly against time as year effects (Figure 14).

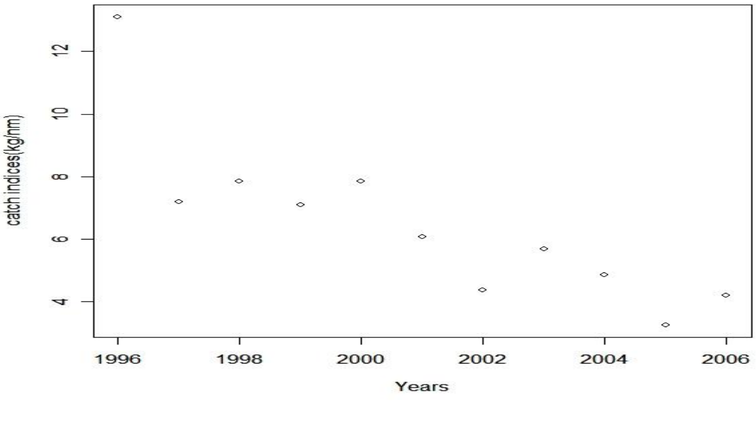

Figure 14: Annual variation of catch rates against time as year effects over the years (1996-2006).

The model drop1 was used to drop the insignificant factor i.e. day time strata (fishing time) from the model and then computed a table of changes in fit (Table 3). In general, CPUE declines over the years. However, in the two consecutive years, 1996 and 1997, drastic fluctuations of CPUE were observed compared to the other years. Catch rate declines very rapidly from 25.24kg/nm to 13.8kg/nm between 1996 and 1997. The catch rate also declines very rapidly from 15.11 to 8.4kg/nm between 2000 and 2002. The catch rate increases marginally from 13.66 to 15.11kg/nm between 1999 and 2000. The lowest value of catch rate over the years is reported to be 6.2kg/nm in the year 2005. The catch rate in the most recent year (i.e. 2006) started increasing appreciably from 6.2kg/nm to 8.9kg/nm. This increase may be a good sign of replenishing of the stock.

Table 3: Annual variation of catch rates against time as a year effects.

YEAR	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Catch indices	25.24	13.8	15.11	13.66	15.11	11.62	8.4	10.94	9.3	6.2	8.9

The estimated coefficients expressing the difference between each level of factors and the first level, derived on the basis of all the significant factors i.e. 5 (variables), are shown in Figure 15.

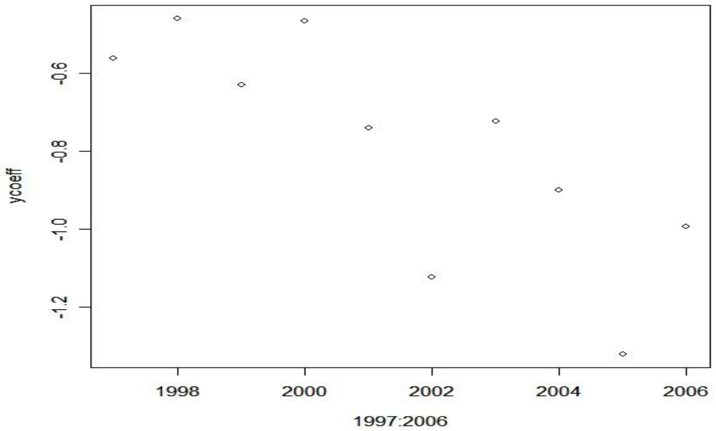

Figure 15: Coefficient expressing the difference between each level of factors and first level against time as year effects over the years (1996-2006).

Unbiased estimates of catch rates are obtained by the anti-logarithm of the estimates of ln(CPUE). However, for the comparison of yearly differences in catch rate, the intercept was replaced by the estimated annual mean ln(CPUE) in 1996 for the real combination of all the factors (Large 1992). The annual variation of catch rates was then plotted directly against time as year effects. In the main effect model, the contribution of each main effect to the variation of *N. japonicus* catch rate is shown in Figure 16.

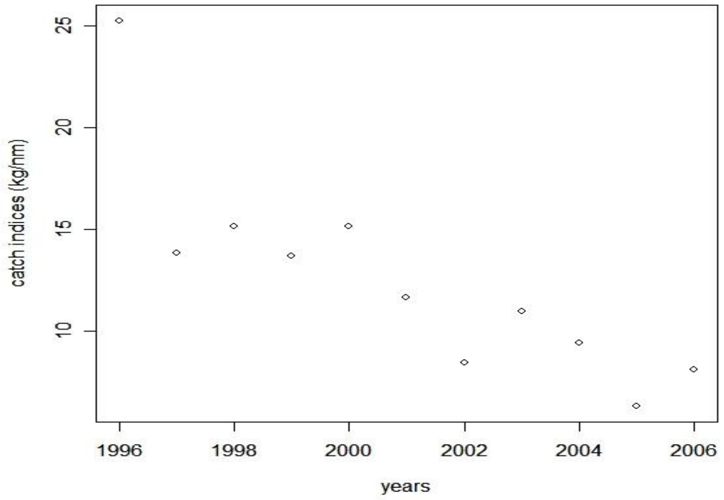

Figure 16: The annual variation of catch rates against time as a year effects.

The model could explain only 19.5% of the deviance, most of which is explained by the difference between latitudes (space) i.e. 6.3%. The variation in ln(CPUE) explained by year is 5.7%. Finally, the factors, quarter (month), depth strata (fishing depth) and towing speed could account for 3.7%, 2%, and 1.7% of the explained model deviance (Table 4).

Table 4: Analysis of deviance table for Gaussian based model fitted to *N. japonicus* catch rate data.

Source of variation	DF	Deviance	%	Resid.df.	Res.deviance	F
Null				5915	13333.9	
FACTOR (LATITUDE STRATA OF 3 N)	6	843.8	6.33	5909	12490.1	***
FACTOR (YEAR)	10	757.6	5.68	5899	11732.5	***
FACTOR (QUARTERS)	3	498.5	3.74	5896	11234	***
FACTOR (DEPTHSTRATA)	3	262.6	1.97	5893	10971.4	***
FACTOR (SPEED STRATA)	1	232.2	1.74	5892	10739.2	***
Total explained			19.46			

6 DISCUSSION

This study reveals that the stock is distributed in various abundances over the study period. Various factors might affect the abundance of *N. japonicus*. Therefore, it would be useful to study the other factors determining the abundance of this species. Furthermore, the study confirms that catch rates of this species along the west coast do not remain constant over the period of study. The survey catch rates of *N. japonicus* caught from the commercial fishing zone show a clear drastic decreasing trend over the study period. The main reason for the declining catch rate of this species could be the excessive fishing pressure due to the increasing number of mechanised fishing boats. The density of fishers per km^2 along the west coast in the past decade has increased tremendously. This excess effort might have resulted in overfishing of the stock of this species. This species spawns almost in all the months but the peak season is reported to be monsoon. The implementation of the monsoon ban along the west coast may enhance the catch rate of this species in the coming years. This species is one of the target species of the trawl fishery. The fishermen target one rather than the other depending on the considerations of the stock abundance, fishing location, market price, etc. The decreasing catch rate of this species may consequently lead to the rising of some other species catch indices.

The further exploitation of this species may not be encouraging to the fishermen. The swing of targeting species is natural, and is an effective way for the fishermen to survive the drastic decline or collapse of some particular fish species. The increase of the catch rate in 2006 may be because of compliance with the monsoon ban or may be due to a swing of target species. The more comprehensive method used in the study would provide more reliable estimates of catch rates than the traditional averaging method.

The analysis of deviance shows that the model could explain only 19.5% of the deviance. The information on other explanatory variables such as environmental factors, some of the interactions, mechanisation, more information on seasonalities etc. is needed to reduce the unexplained deviance and to enhance the reliability of the model.

The results of this study indicate that using GLMs to analyse catch rates of the species *N. japonicus* is a sensible method for obtaining standardised indices. However, this fishery is well documented but unfortunately the valuable information is not available at this moment for verifying the reliability of the estimated year-to-year variation in the catch rate. It would always be desirable to compare the standardised catch rates derived from resource surveys with the estimates derived from the commercial catch rates or catch rate studies if they were avaliable. Caution should be exercised when catch rates are to be compared with stock abundance indices because catch rates may not be closely related to abundance, particulary when some of the important factors that influence catch rates are not considered in the GLM analysis.

7 CONCLUSION

The data used in this study are highly unbalanced. The GLM in the R-package can take the unbalanced data into account, which can be a great advantage, but the precision would be improved by a more balanced design. Probably, the precision of the estimates of the coefficients would have increased considerably, had the other associated information collected in the surveys on wind direction, wind velocity, current speed, current velocity, bottom type, trawling speed etc. been included in the GLM analysis. The precision would definitely have increased considerably had the survey been done in accordance with the planned survey scheme.

The models can accommodate temporal and spatial variability as well as the variability of other categories such as gear type, vessel horse power, length of the vessel, skipper's skill and environmental factors. The environmental factors such as temperature, salinity and oxygen are basically responsible for the spatial and temporal distribution of the fish. Most of the FSI's vessels are well equipped with the oceanographic equipments. The environmental data available with FSI, may also be tried. The inclusion of these factors in the GLM analysis would definitely affect the estimates of the coefficients .This should be a concern in the future survey.

This report provides substantial information on temporal and spatial variability in abundance of *N. japonicus* caught between the 1996 and 2006 along the west coast of India. This information could be used as the basis of stock assessments and management.

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LIST OF REFERENCES

Allen, R. and Punsley, R. 1984. Catch rates as indices of abundance of yellowfin tuna *Thunnus albacares* in the eastern Pacific Ocean.*Int. American Tropical Tuna Commission. Bulletin* **18**: 301–379.

Brynjarsdóttir, J. and Stefánsson, 2004. G. Analysis of cod catch data from Icelandic groundfish surveys using generalized linear models, *Fisheries Research* **70**: 195–208.

Beverton, R. J. H. and Holt, S. J. 1957. *On the Dynamics of Exploited Fish Populations*, London: HMSO.

Battaile, B.C. and Quinn II, T.J. 2004. Catch per unit effort standardization of the eastern Bering Sea walleye Pollock (*Theragra chalcogramma*) fleet. *Fisheries Research* **70** : 161–177.

Chambers, J.M. and Hastie, T.J., 1992. Statistical models in S. , Wadsworth, Pacific Grove, CA.

Campbell, R. 2004. CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models.*Fisheries. Research* **70:** 209–227.

Campbell, R .2004. CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. *Fisheries Research* **70:** 209–227.

CMFRI REPORT 1996 – 2006. Central Institute of Marine Fisheries, cochin India.

Dunn, A., Harley, S.J., Doonan, I.J. and Bull, B. 2000. Calculation and interpretation of catch-per-unit-effort (CPUE) indices. *New Zeland Fisheries Association Report No. 2000/1.*

Goñi, R., Alvarez, S. and Adlerstein, R.A. 1999. Application of generalized linear modeling to catch rate analysis of Western Mediterranean fisheries: the Castellón trawl fleet as a case study. *Fisheries. Research* **42:** 291–302.

Hilborn, R.and Walters,C.J. 1992. *Quantitative Fisheries Stock Assessment*, London: Chapman & Hall.

Lambert, D .1992. Zero-inflated Poisson regression, with application to random defects in manufacturing.*Technometrics* **34**: 1–14.

Large, P.A .1992. Use of a multiplicative model to estimate relative abundance from commercial CPUE data, *ICES J. Marine Science* **49**: 253–261.

McCullagh ,P. and Nelder, J.A .1989. *Generalised Linear Models* (2nd ed.). London Chapman & Hall.

Maunder, M.N. 2001. A general framework for integrating the standardization of catch per unit of effort into stock assessment models, *Canadian Journal of Fisheries Aquatic Science* **58** : 795–803

Maunder, M.N.and Punt, A.E. 2004. Standardizing catch and effort data: a review of recent approaches. *Fisheries. Research* 70**:** 141-159.

MoA. Ministry of Agriculture, New Delhi. Website: http://dahd.nic.in/

Nishida, T.and Chen, D.G.2004. Incorporating spatial autocorrelation into the general linear model with an application to the yellowfin tuna (*Thunnus albacares*) longline CPUE data. *Fisheries. Research* 70: 265-274.

Ortiz ,M and Arocha ,F. 2004. Alternative error distribution models for standardization of catch rates of non-target species from a pelagic longline fishery: billfish species in the Venezuelan tuna longline fishery.*Fisheries Research* **70**: 275–294.

Porch, C.E. and Scott, G.P .1994. A numerical evaluation of GLM methods for estimating indices of abundance from West Atlantic bluefin tuna catch per trip data when a high proportion of the trips are unsuccessful.*International Commission For Conservation of Atlantic ,Col. Vol. Sci. Pap* 42 :241-245

Quinn II , T.J. and Deriso, R.B. 1999.*Quantitative Fish Dynamics* New York: Oxford University Press.

Ricker, W. E. 1973 .Linear regressions in fishery research. *Journal of Fisheries Research Board Canada* 30: 409–434.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of Fisheries Research Board Canada*191: 1–382.

Robson, D.S. 1966. Estimation of the relative fishing power of individual ships.*ICNAF Research Bulletin 3* : 5–14.

Schnute, J.T .1977. Improved estimates from the Schaefer production model: theoretical considerations. *Journal of Fisheries Research Board Canada* 34**:** 583–603.

Stephens, A. and MacCall, A. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. *Fish*eries. *Research* 70: 295–306.

Stefánsson ,G .1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches.*ICES Journal of Marine Science* 53: 577–588.

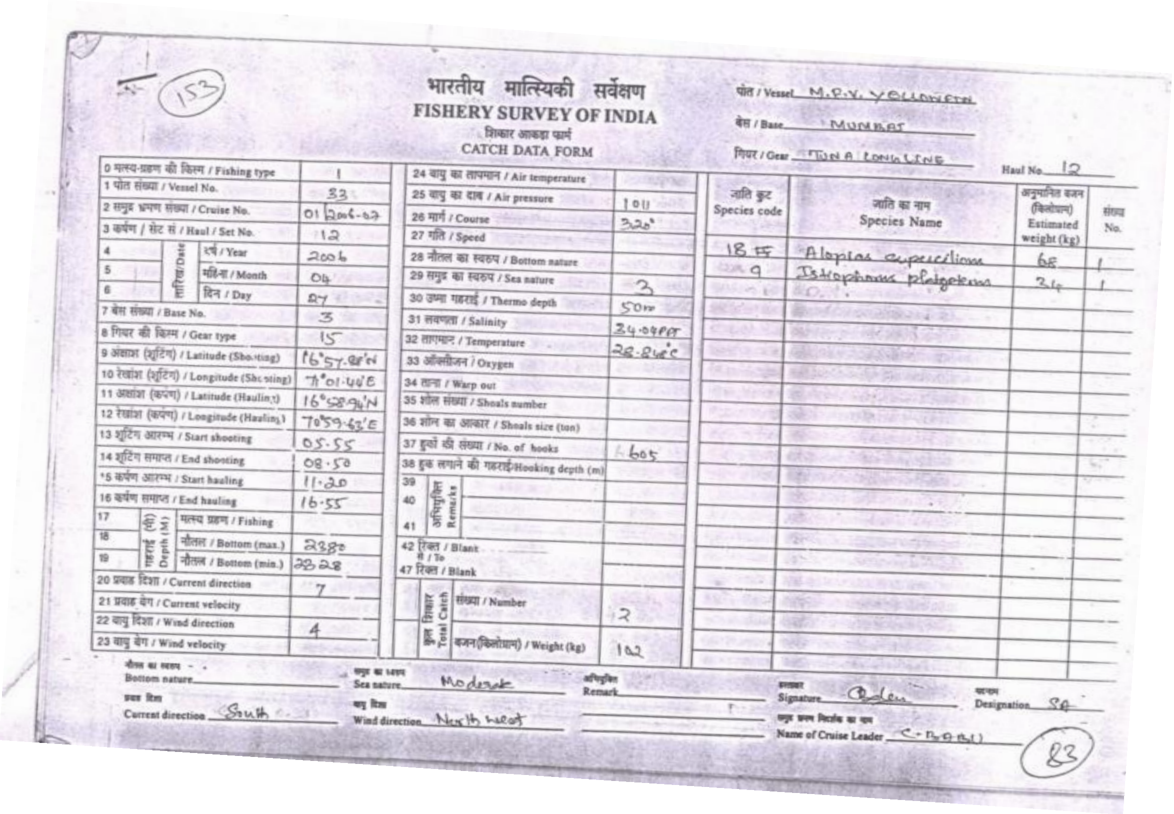
Venables,W.N.and Ripely,B.D. 2002. Modern Applied Statistics with S.4th ed.New York: Springer.

Vivekanandan, E., M. Srinath, V.N. Pillai, S. Immanuel and K.N. Kurup 2003. Marine fisheries along the southwest coast of India, p. 757 - 792. In G. Silvestre, L. Garces, I. Stobutzki, C. Luna, M. Ahmad, R.A. Valmonte-Santos, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.). Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. World Fish Center Conference Proceedings 67, 1-120

Westrheim, S.J. and Foucher, R.P. 1985. Relative fishing power for Canadian trawlers landing Pacific cod (*Gadus macrocephalus*) and important shelf cohabitants from major offshore areas of western Canada.*Canadian Journal of Fisheries Aquatic Science* 42**:** 1614–1626.

Zacharia, P.U. 1998. Dynamics of the. thread fin bream, *N. japonicus*. exploited off Karnataka. Indian Journal of fisheries 45(3):265- 270.

Appendix 1: A trawl log format (catch data sheet designed by the scientists of Fishery Survey of India)



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भारतीय मात्स्यिकी सर्वेक्षण
FISHERY SURVEY OF INDIA
शिकार आकड़ा फार्म
CATCH DATA FORM

पोत / Vessel M.P.V. YELLOWFIN
बेस / Base MUMBAI
गियर / Gear TUNA LONGLINE
Haul No. 12

0 मत्स्य-ग्रहण की किस्म / Fishing type		1
1 पोत संख्या / Vessel No.		33
2 समुद्र भ्रमण संख्या / Cruise No.		01 2006-07
3 कर्षण / सेट सं / Haul / Set No.		12
4	तारीख/Date वर्ष / Year	2006
5	महीना / Month	04
6	दिन / Day	27
7 बेस संख्या / Base No.		3
8 गियर की किस्म / Gear type		15
9 अक्षांश (शूटिंग) / Latitude (Shooting)		16°57.98'N
10 रेखांश (शूटिंग) / Longitude (Shooting)		71°01.44'E
11 अक्षांश (कर्षण) / Latitude (Hauling)		16°58.94'N
12 रेखांश (कर्षण) / Longitude (Hauling)		70°59.63'E
13 शूटिंग आरम्भ / Start shooting		05.55
14 शूटिंग समाप्त / End shooting		08.50
15 कर्षण आरम्भ / Start hauling		11.20
16 कर्षण समाप्त / End hauling		16.55
17	गहराई (मी) Depth (M) मत्स्य ग्रहण / Fishing	
18	नौतल / Bottom (max.)	2380
19	नौतल / Bottom (min.)	2328
20 प्रवाह दिशा / Current direction		7
21 प्रवाह वेग / Current velocity		
22 वायु दिशा / Wind direction		4
23 वायु वेग / Wind velocity		

24 वायु का तापमान / Air temperature		
25 वायु का दाब / Air pressure		1011
26 मार्ग / Course		320°
27 गति / Speed		
28 नौतल का स्वरुप / Bottom nature		
29 समुद्र का स्वरुप / Sea nature		3
30 उष्मा गहराई / Thermo depth		50m
31 लवणता / Salinity		34.04PPT
32 तापमान / Temperature		28.84°C
33 ऑक्सीजन / Oxygen		
34 ताना / Warp out		
35 शोल संख्या / Shoals number		
36 शोल का आकार / Shoals size (ton)		
37 हुकों की संख्या / No. of hooks		605
38 हुक लगाने की गहराई/Hooking depth (m)		
39	अभियुक्ति Remarks	
40		
41		
42 रिक्त / Blank से / To 47 रिक्त / Blank		
कुल शिकार Total Catch	संख्या / Number	2
	वजन(किलोग्राम) / Weight (kg)	102

जाति कूट Species code	जाति का नाम Species Name	अनुमानित वजन (किलोग्राम) Estimated weight (kg)	संख्या No.
18 FF	Alopias superciliosus	68	1
9	Istiophorus platypterus	34	1

नौतल का स्वरुप
Bottom nature

समुद्र का स्वरुप
Sea nature Moderate

अभियुक्ति
Remark

प्रवाह दिशा
Current direction South

वायु दिशा
Wind direction North west

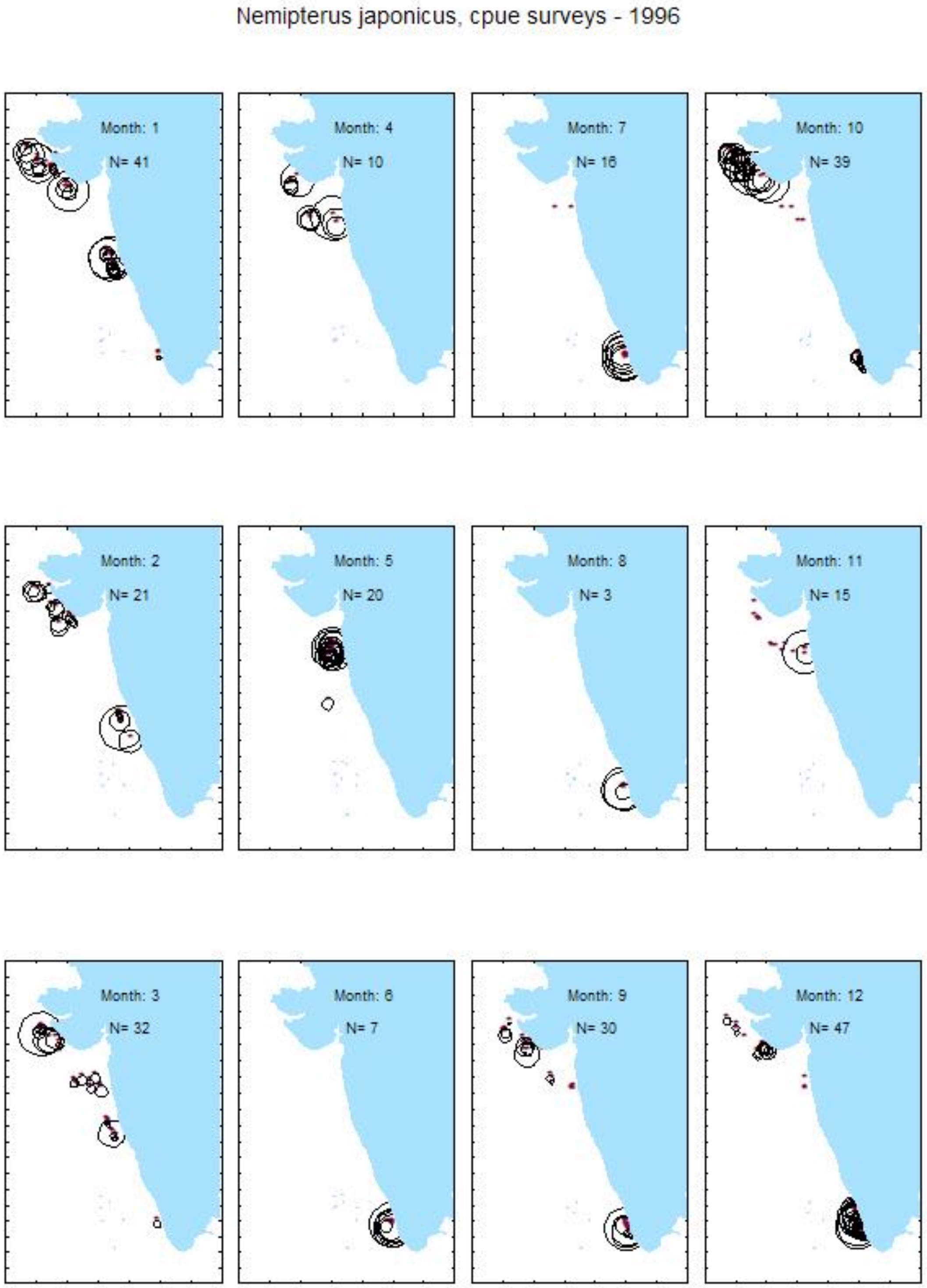
हस्ताक्षर
Signature

पदनाम
Designation SA

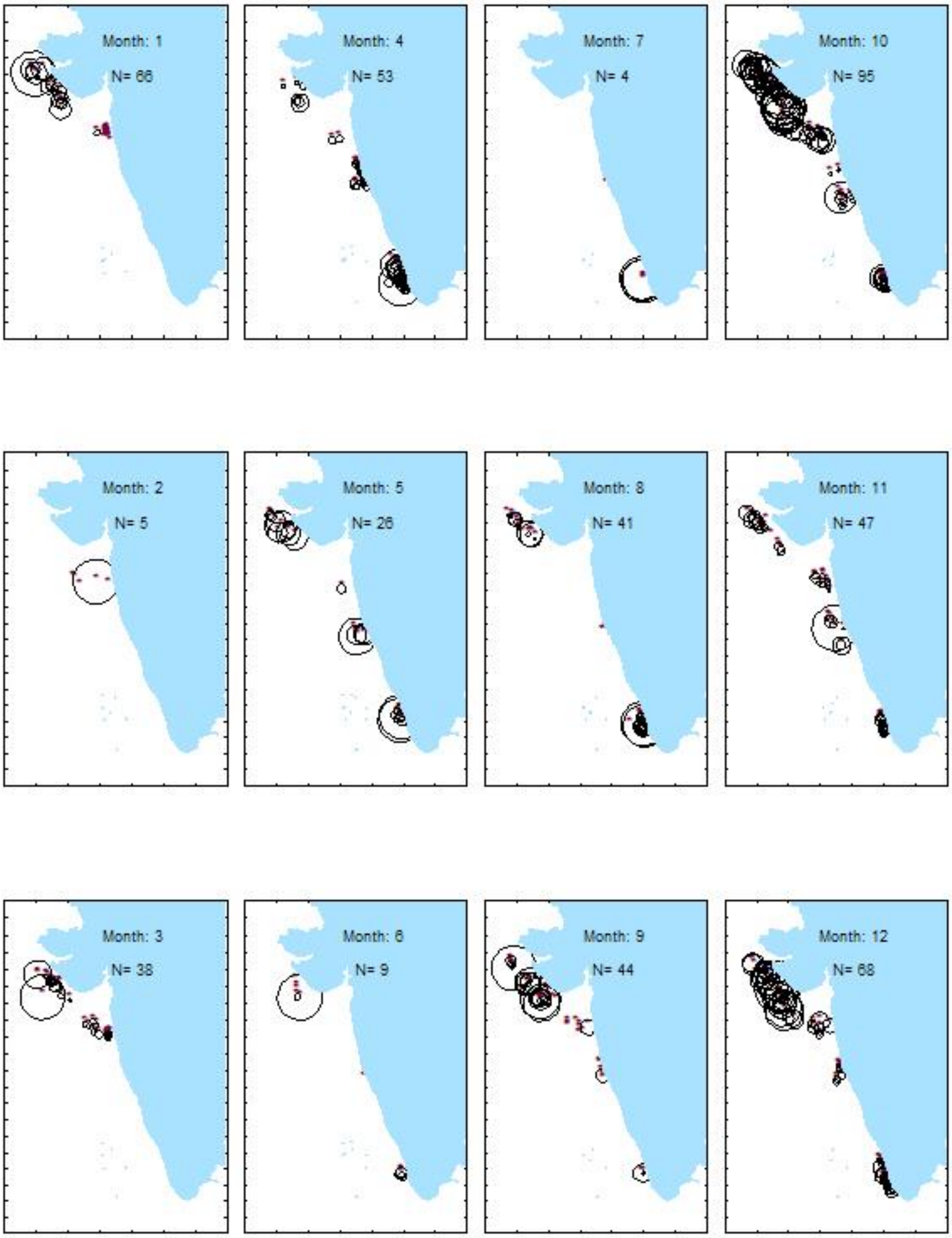
समुद्र भ्रमण निदेशक का नाम
Name of Cruise Leader C. [illegible]

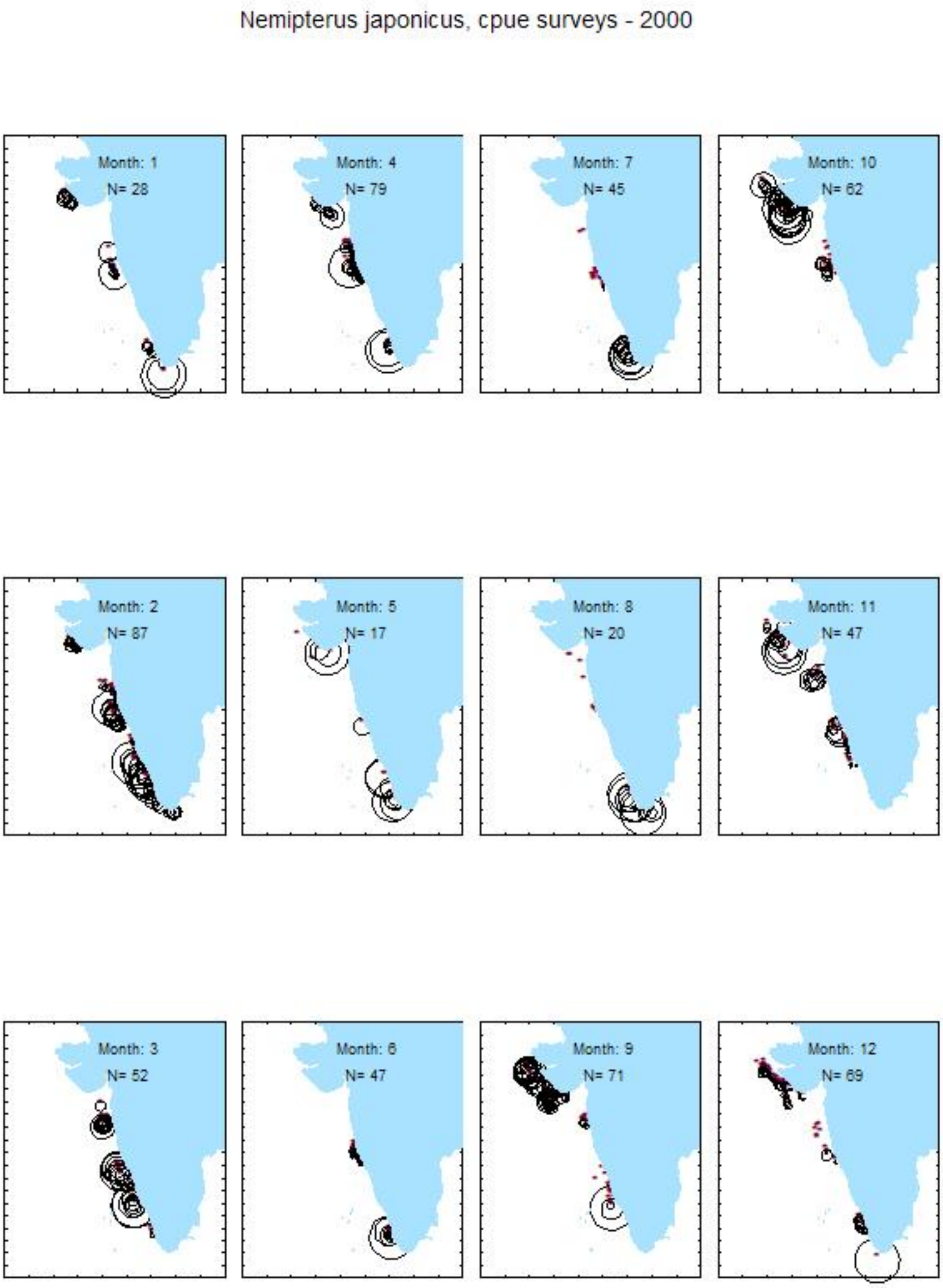
83

Appendix 2: The distribution of sampling stations over the space and among months.

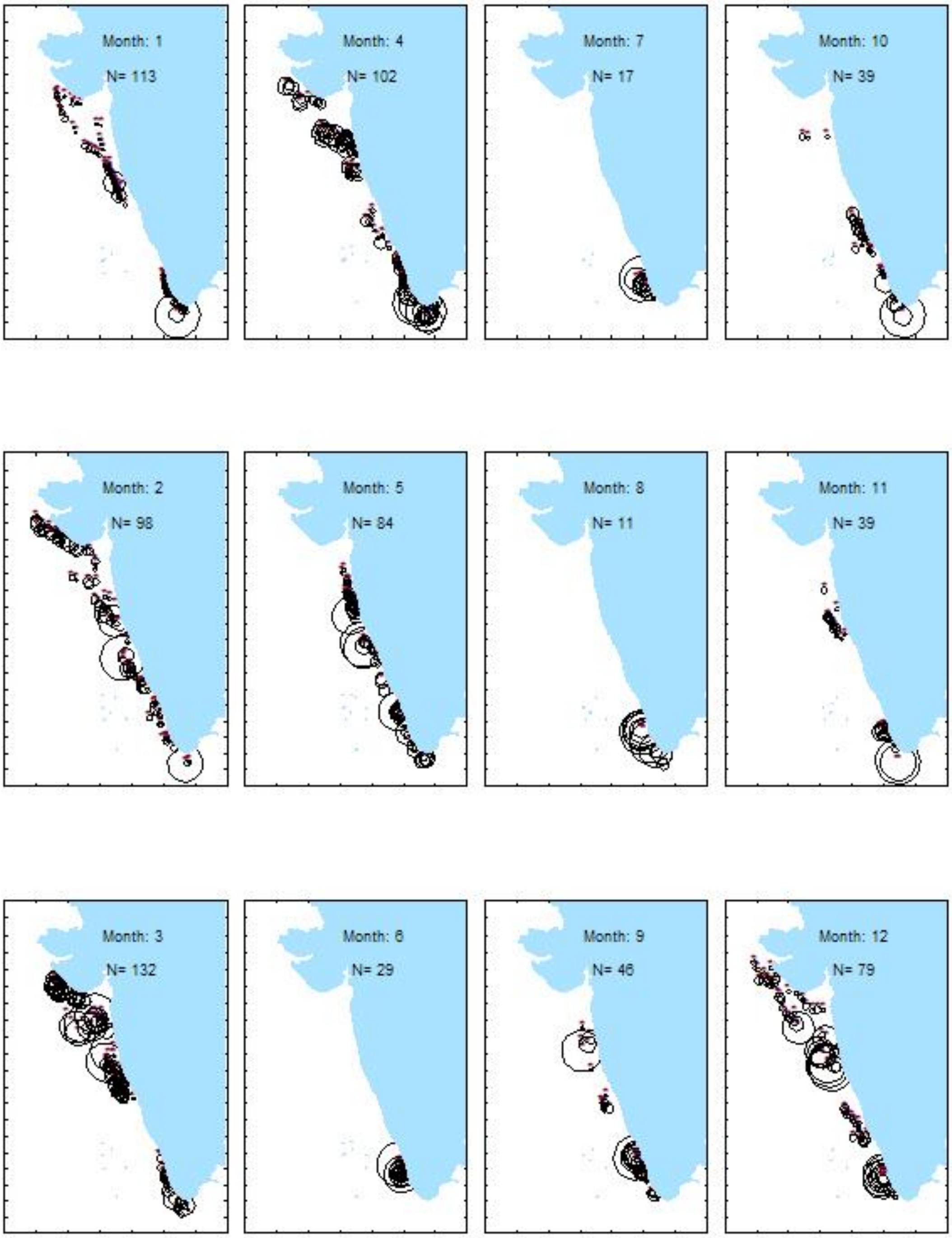


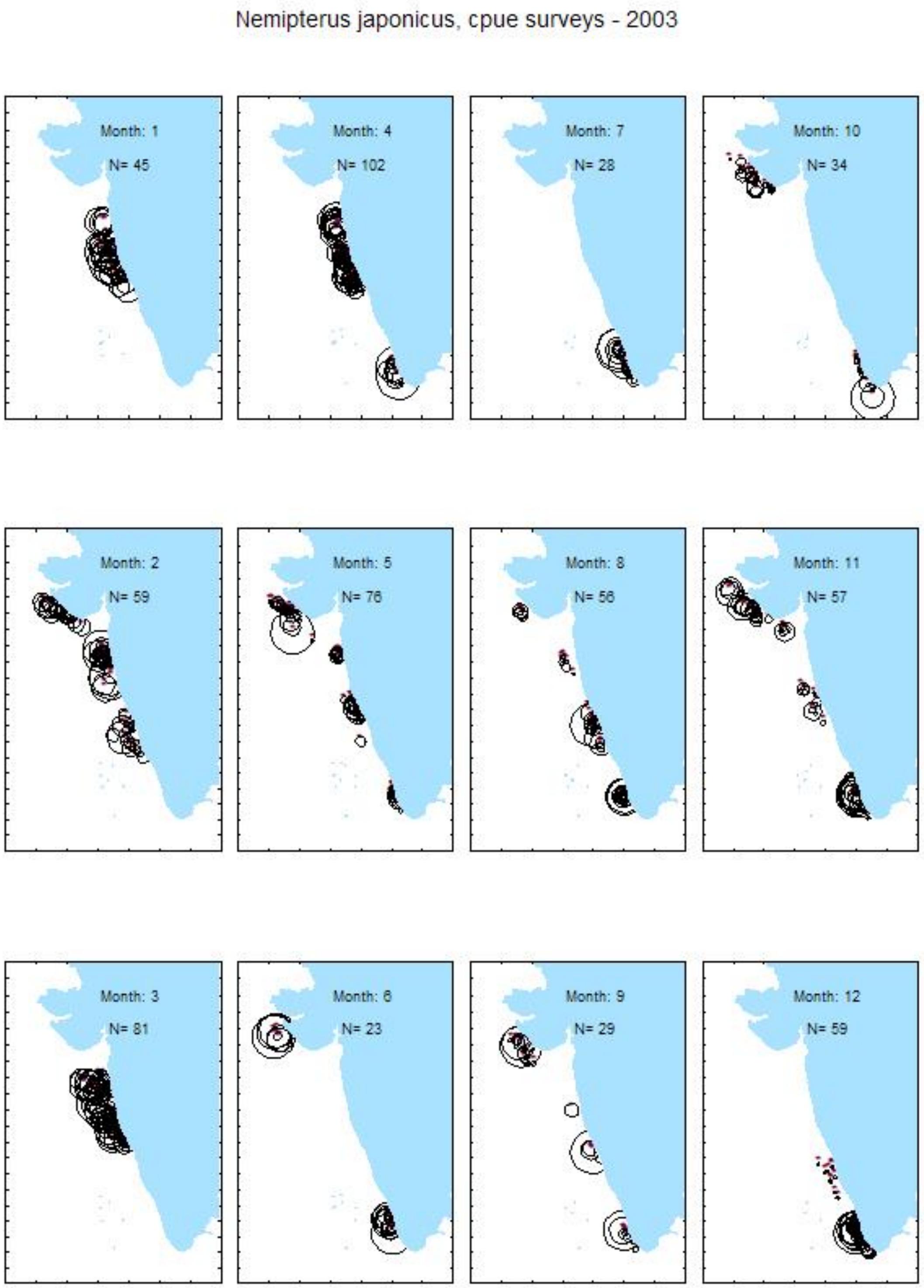
Nemipterus japonicus, cpue surveys - 1997



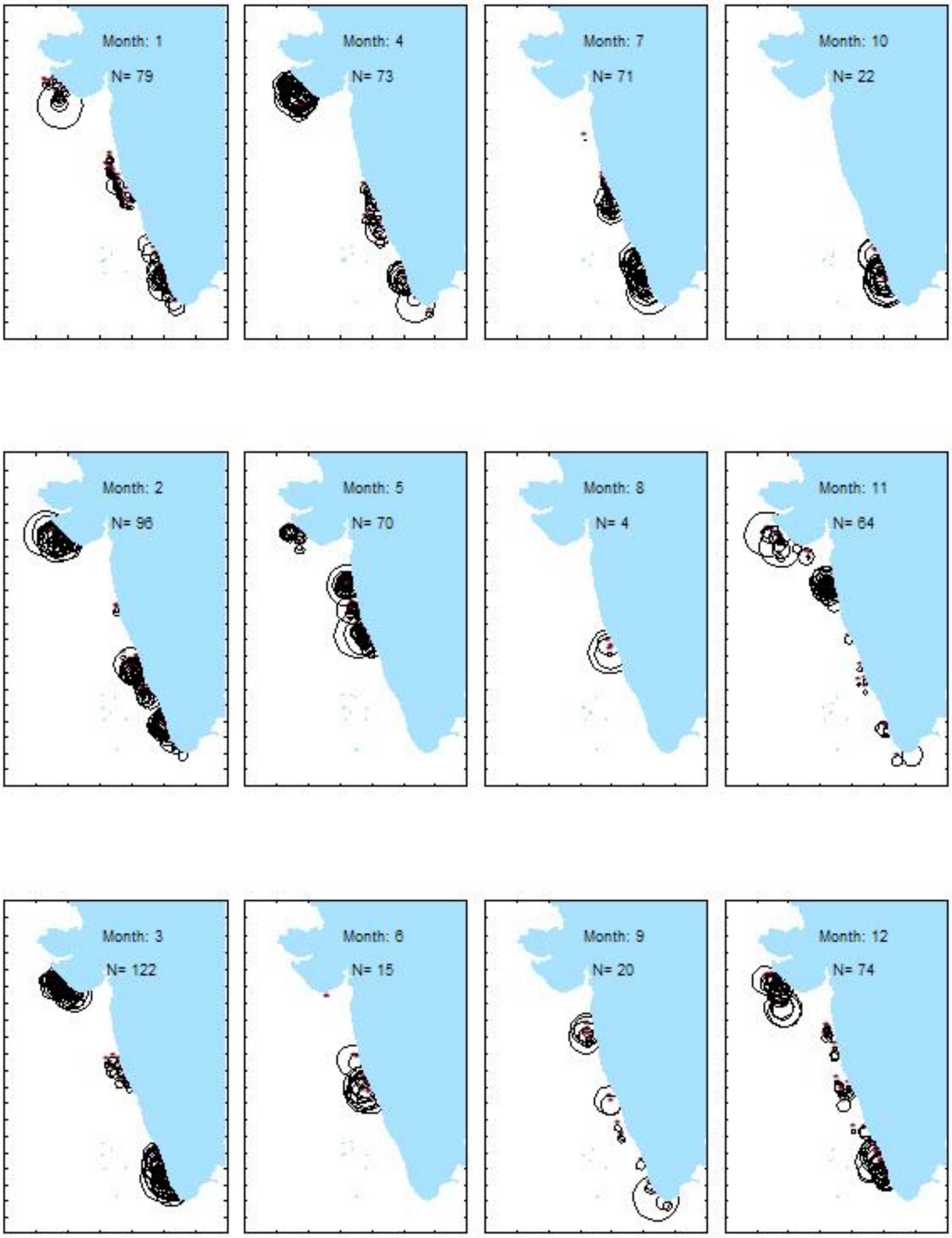

Nemipterus japonicus, cpue surveys - 2000
Month: 1
N= 28
Month: 4
N= 79
Month: 7
N= 45
Month: 10
N= 62
Month: 2
N= 87
Month: 5
N= 17
Month: 8
N= 20
Month: 11
N= 47
Month: 3
N= 52
Month: 6
N= 47
Month: 9
N= 71
Month: 12
N= 69

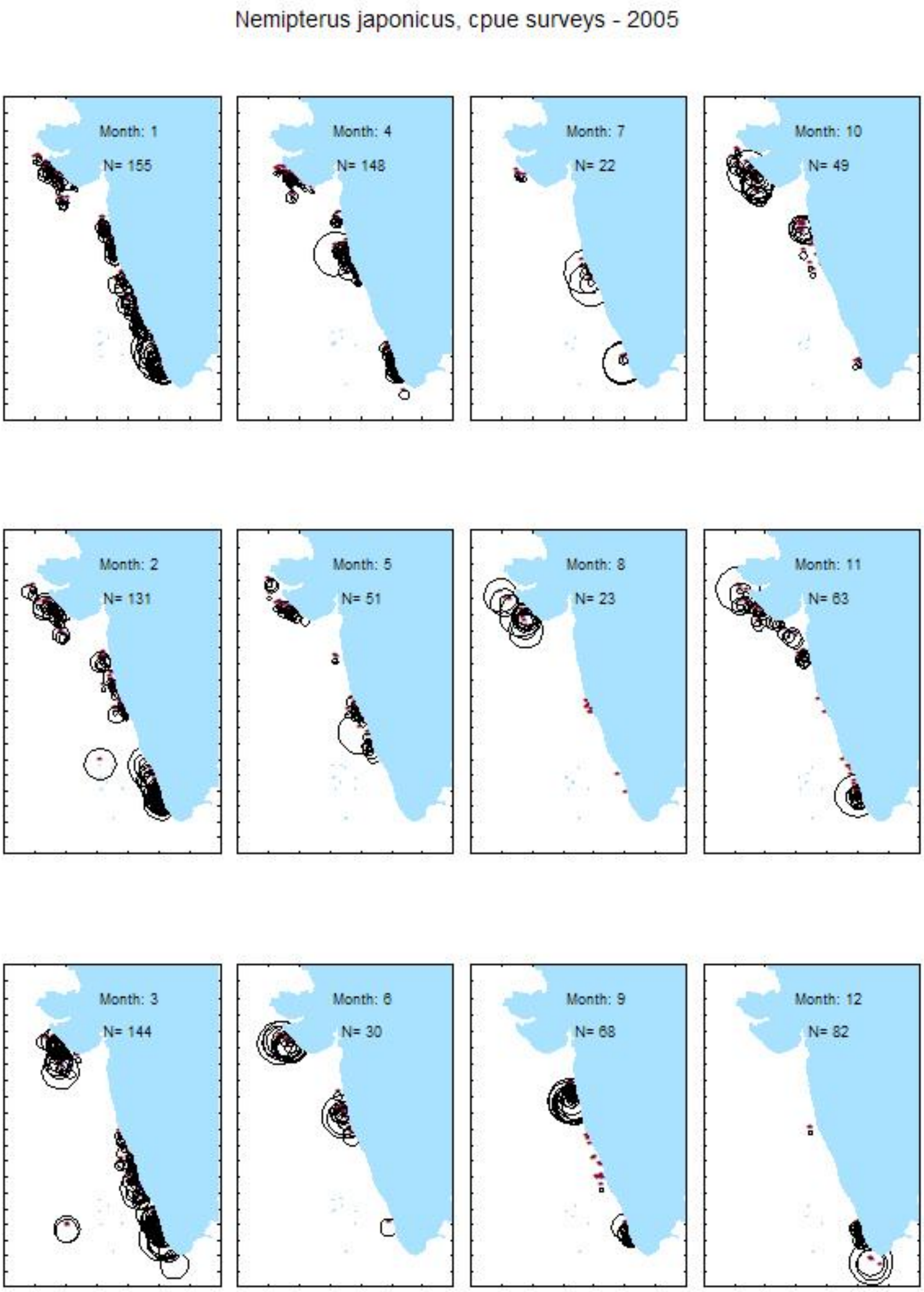
Nemipterus japonicus, cpue surveys - 2002



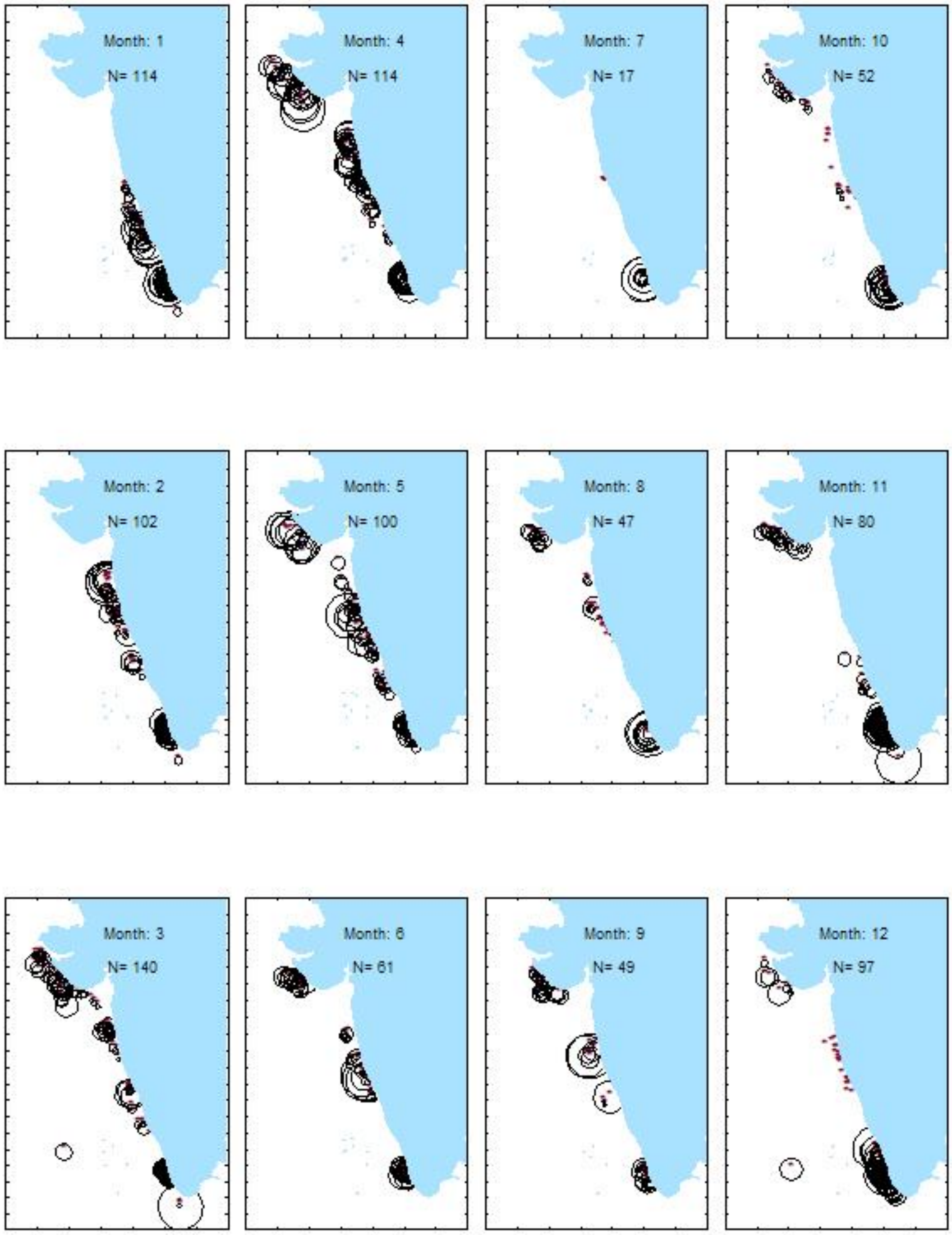

Nemipterus japonicus, cpue surveys - 2003
Month: 1
N= 45
Month: 4
N= 102
Month: 7
N= 28
Month: 10
N= 34
Month: 2
N= 59
Month: 5
N= 76
Month: 8
N= 56
Month: 11
N= 57
Month: 3
N= 81
Month: 6
N= 23
Month: 9
N= 29
Month: 12
N= 59

Nemipterus japonicus, cpue surveys - 2004




Nemipterus japonicus, cpue surveys - 2005
Month: 1
N= 155
Month: 4
N= 148
Month: 7
N= 22
Month: 10
N= 49
Month: 2
N= 131
Month: 5
N= 51
Month: 8
N= 23
Month: 11
N= 63
Month: 3
N= 144
Month: 6
N= 30
Month: 9
N= 68
Month: 12
N= 82

Nemipterus japonicus, cpue surveys - 2006



Distribution of sampling stations over the space and among the years