Temporal Behaviour of Marine Landings Along Coastal Karnataka III. Cyclical Patterns*

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Marine landing data for Karnataka during 1956–1978 were subjected to time-series analysis and cyclical periodicities isolated in the case of seven fisheries namely, ribbon fish (five year cycle); *Caranx* spp., *Leiognathus* spp. and mackerel (six year cycle each); the combined landings of *Hemirhamphus* spp. and *Belone* spp., 'Lesser Sardines' and 'Other Clupeids' (seven year cycle each). 'Total' demonstrated an eight-year cyclical periodicity.

The availability of certain fish resources is known to follow a cyclical periodicity. The pink salmon *Onchorhyncus gorbuscha* is a widely studied one and considerable information is available on its biology and ecology. Based on his studies on this fish, Birman (1976) demonstrated the occurrence of periodicities in abundance, specifically a two-year and a four-year periodicity in the abundance of the pink salmon. The two-year periodicity is apparently a wide-spread phenomenon which has been observed in plants (LeRoy-Ladurie, 1971) and in meteorological elements in temperate latitudes (Ugryumov, 1968). Birman (1976) found that the sock-eye salmon revealed a dependency on climate, especially solar activity, when a four-year periodicity in abundance occurred. Regular rhythmic fluctuations in climatic conditions and consequent hydrographic fluctuations possibly influence the life history of any aquatic population and fish is no exception.

The present study was undertaken to study the temporal behaviour of fish landings along coastal Karnataka and in the process, to look for cyclical (of period more than one year) periodicities.

Material and Methods

Quarterly marine catch-statistics in metric tonnes for coastal Karnataka (12° 44′ N to 14° 53′ N) were obtained from the Central Marine Fisheries Research Institute, Cochin, for the period 1956 to 1978, for 'Total' landings as well as individual figures for 21 species/groups. The data for the period 1956–59 however, was available only for eight fisheries.

The decomposition of the time-series data into its components was carried out by assuming a multiplicative model which is expected to fit the data better than an additive model (Croxton *et al.*, 1967). Under the multiplicative model, an observation O_t (fish catch) pertaining to a specific time point 't' is a result of four influence, namely, a trend effect (T_t), a seasonal effect (S_t), a cyclical effect (C_t) and a random (irregular) component (I_t), conceived mathematically in a multiplicative form, namely,

$$O_t = T_t.\ C_t.\ S_t.\ I_t$$

These four components were estimated from the data on fish landings by standard methods (Croxton *et al.*, 1967). The seasonal indices were estimated first, using which, the original observations O_t were deseasonalized by dividing by S_t to give the final estimate of TCI. These estimates ($\widehat{TCI}$'s) were then plotted on a graph against time, to check if any periodic (cyclical) pattern was discernible visually. Wherever an oscillatory pattern was suggestive, a centered moving average of an appropriate period was worked out to eliminate this cyclical component, leaving only $\hat{T}$ which constituted the secular trend of the species/group under consideration.

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An improved and final cyclical effect 'C' was obtained in the following manner. The $\widehat{TCI}$'s were divided by the $\hat{T}$'s to give $\widehat{CI}$'s (the cycles along with the 'Irregular' component). To remove this 'I' effect from these cycles, that is to smoothen the cycles, an appropriate simple moving average was computed. The corresponding points in the different cycles were then averaged to give the cyclical indices for the species/group under consideration. In order to ascribe a mathematical format to the said indices as well as to join them by a smooth curve, harmonic analysis was carried out using the procedure given in Douglas (1964).

"In general, there is the result that with 'r' intervals it is worth carrying out this kind of analysis only as far as the $(\frac{r}{2}-1)^{th}$ harmonic" (Bajpai *et al.,* 1977). In the present study, however, in spite of the fact that the number of intervals varied from 20 (five year cycle) to 32 (eight year cycle), it was not found necessary to go beyond the fifth harmonic as the fit was found visually adequate.

Results and Discussion

The results of the time-series analysis pertaining to cyclical patterns alone are presented in this paper. The identification of cyclical periodicity is much more difficult than that of seasonal patterns, since pseudo-cyclical periodicities are likely to be induced into the moving average trend due to the Slutzky-Yule effect (Nerlove *et al.,* 1979). Hence cycles are identified and commented upon only wherever they are obvious.

As many as seven out of the 21 species/groups considered in this study exhibited a distinct cyclical pattern of period ranging from five to seven years. They are ribbon fish (five year cycle); *Caranx* spp. *Leiognathus* spp. and mackerel (six year cycle each); and the combined landings of *Hemirhamphus* spp. and *Belone* spp., 'lesser sardines' and 'other clupeids' (seven year cycle each). 'Total' exhibited a cycle of period eight years. Since the periods were large and the data available was only for 19–23 years, the number of cycles in each was less. However, the oscillatory behaviour of the deseasonalized data was quite apparent. Table 1

Table 1. *Cyclical indices (quarterly) pertaining to seven species/groups and the 'Total'*

Year	1				2				3				4			
species/group	IQ	IIQ	IIIQ	IVQ	IQ	IIQ	IIIQ	IVQ	IQ	IIQ	IIIQ	IVQ	IQ	IIQ	IIIQ	IVQ
Ribbon fish	83	180	170	154	125	171	182	128	195	94	79	63	66	43	35	42
Caranx spp.	52	113	128	165	122	121	133	137	167	133	142	140	207	143	108	58
Leiognathus spp.	107	98	129	119	126	112	107	104	113	138	96	61	71	72	79	73
Mackerel	94	185	264	264	112	71	77	161	151	137	76	41	49	22	30	47
Hemirhampus spp. and *Belone* spp.	132	103	115	312	371	371	161	142	57	62	30	22	119	146	157	55
Lesser Sardines'	104	93	221	339	328	224	85	89	72	82	98	128	110	65	61	82
'Other clupeids'	98	92	168	191	222	157	98	142	60	72	77	86	73	71	68	68
'Total	131	108	122	149	138	118	118	133	97	97	109	116	93	88	90	94

	5				6				7				8			
Ribbon fish	56	78	63	73												
Caranx	72	66	78	50	50	60	68	65								
Leiognathus spp.	60	63	85	82	77	45	72	78								
Mackerel	33	29	29	46	52	78	97	108								
Hemirhampthus spp. and *Belone* spp.	41	31	34	20	24	21	44	65	78	66	103	125				
'Lesser sardines'	107	167	152	139	43	27	15	25	40	73	83	63				
'Other clupeids'	107	128	127	107	90	81	91	100	119	123	103	69				
'Total'	100	92	116	86	64	55	49	86	96	125	114	115	90	70	96	113

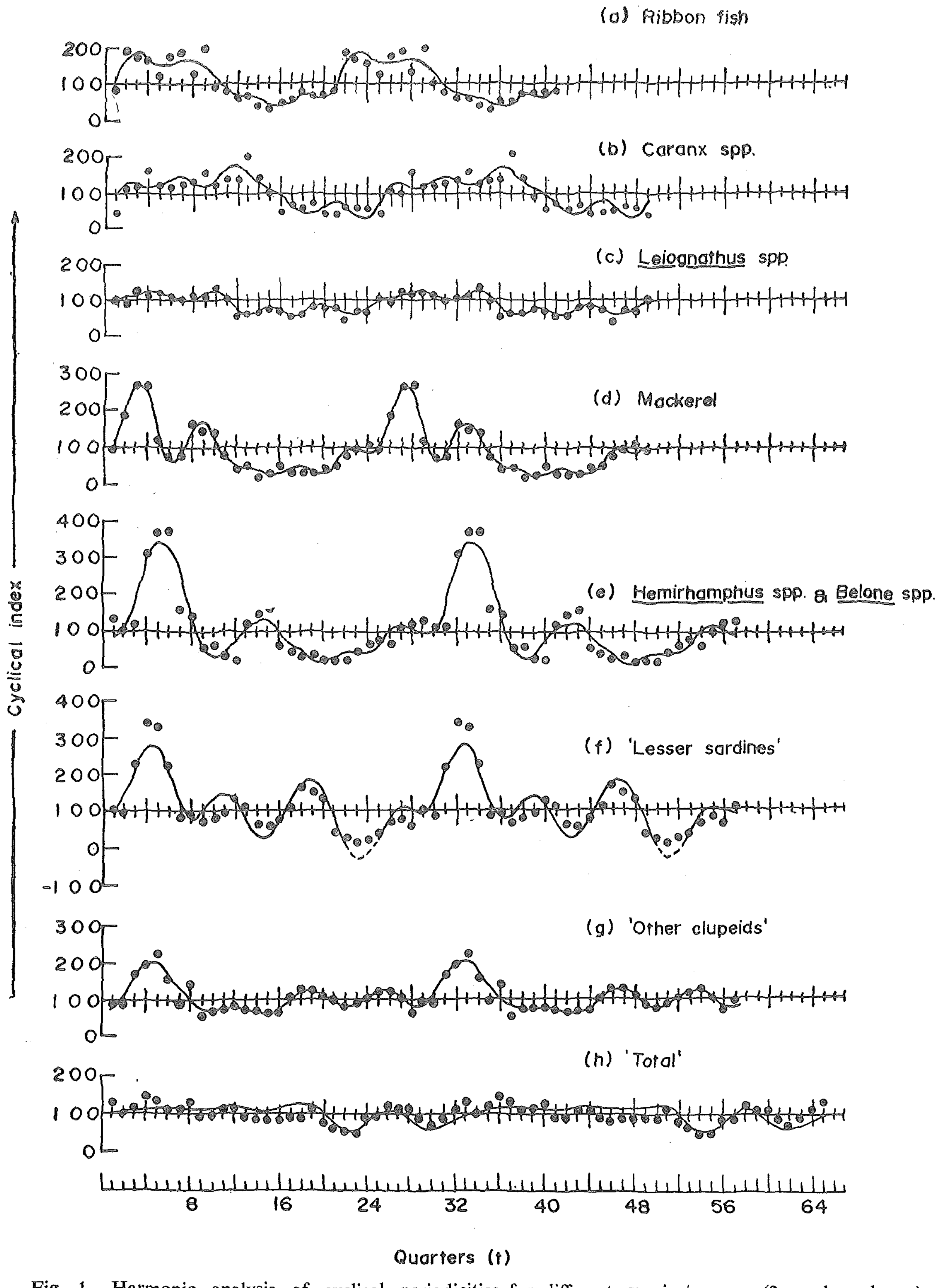

Fig. 1. Harmonic analysis of cyclical periodicities for different species/groups (2 cycles shown)

Table 2. *Harmonic analysis for cyclical indices*

Species/group		Functional format of f (t)*					Reference to Fig 1
Ribbon fish	104,0	–46.55 Cos (t)	– 33.3 Cos 2 (t)	– 7.89 Cos 3 (t)	+16.35 Cos 4 (t)	+10.60 Cos 5 (t)	(a)
		+45 86 Sin (t)	– 0.29 Sin 2 (t)	–11.47 Sin 3 (t)	– 5.30 Sin 4 (t)	+0.40 Sin 5 (t)	
Caranx spp.	107.42	–49.88 Cos (t)	– 4.84 Cos (2 (t)	+3.90 Cos 3 (t)	– 3 58 Cos 4 (t)	+7 98 Cos 5 (t)	(b)
		+11.90 Sin (t)	+11.77 Sin 2 (t)	–15.43 Sin 3 (t)	– 7.11 Sin 4 (t)	–18.51 Sin 5 (t)	
Leiognathas spp.	90.29	–26.47 Cos (t)	+4.94 Cos 2 (t)	+8.89 Cos 3 (t)	– 3.88 Cos 4 (t)	+8.44 Cos 5 (t)	(c)
		+7.42 Sin (t)	– 4.19 Sin 2 (t)	– 3.81 Sin 3 (t)	+6.24 Sin 4 (t)	+8.26 Sin 5 (t)	
Mackerel	93.88	–69.26 Cos(t)	+14.86 Cos 2 (t)	–26.47 Cos 3 (t)	+36.21 Cos 4 (t)	–26.09 Cos 5 (t)	(d)
		–25.38 Sin (t)	– 5.92 Sin 2 (t)	+14.00 Sin 3 (t)	+13.12 Sin 4 (t)	–17.32 Sin 5 (t)	
Hemirhamphus spp.	107.39	–81.86 Cos (t)	+11.40 Cos 2 (t)	–31.25 Cos 3 (t)	+20.80 Cos 4 (t)	+11.20 Cos 5 (t)	(e)
and *Belone* spp.		+34.43 Sin (t)	–48.19 Sin 2 (t)	+56.89 Sin 3 (t)	–30.96 Sin 4 (t)	+13.05 Sin 5 (t)	
'Lesser sardines'	111.25	–51.73 Cos (t)	+18.66 Cos 2 (t)	+11.04 Cos 3 (t)	–28.93 Cos 4 (t)	+16.06 Cos 5 (t)	(f)
		+10.29 Sin (t)	–64.41 Sin 2 (t)	–18.21 Sin 3 (t)	–51.69 Sin 4 (t)	+10.12 Sin 5 (t)	
'Other clupeids'	106.71	–14.80 Cos (t)	+18.96 Cos 2 (t)	– 6.26 Cos 3 (t)	–15.54 Cos 4 (t)	+2.28 Cos 5(t)	(g)
		+24.92 Sin (t)	–24.91 Sin 2 (t)	+13.00 Sin 3 (t)	–22.73 Sin 4 (t)	–3.23 Sin 5(t)	
'Total'	102.03	–17.03 Cos (t)	– 0.66 Cos 2 (t)	– 0.44 Cos 3 (t)	–5.58 Cos 4 (t)	–0.78 Cos 5(t)	(h)
		–12.22 Sin (t)	– 2.45 Sin 2 (t)	+12.11 Sin 3 (t)	+14.72 Sin 4 (t)	+9.32 Sin 5(t)	

*General functional form of f (t) : $f(t) = A_0 + A_n \operatorname{Cos} n(t) + B_n \operatorname{Sin} n(t)$, where

t = angular transformation of time interval i.e. $O \leq t \leq 2\pi$

with an increase of $\frac{2\pi}{p}$ degrees per interval (p = period of cycle in terms of quarters)

A_0, A_n and B_n are parameters of the equation presents the cyclical indices pertaining to each of the seven species/groups and the 'Total.' Since the data presented in the Table are indices, the figures are not absolute. Instead, they are relative to the trend-a base of value 100. Again, the 'years' denoted in the Table simply pertain to the respective periods of the different species/group and do not refer to any specific point in time.

Harmonic analysis (upto the fifth harmonic only) was carried out using the cyclical indices for each of the seven fisheries and for the 'Total.' The results are presented in Fig. 1 and the mathematical format that f(t), the cylical function assumes in each case, is given in Table 2.

As is evident from the Figure 1A and Table 1, the amplitude is maximum in the case of the combined landings of *Hemirhamphus* spp. and *Belone* spp., followed by 'lesser sardines', mackerel, 'other clupeids', *Caranx* spp. ribbon fish and *Leiognathus* spp. These amplitudes are relative to a base (trend) of value 100 and reflect the systematic fluctuations over the years from this base. The quarterly average landings of these seven fisheries are as follows: ribbon fish (72 tonnes) *Caranx* spp. (172 t), *Leiognathus* spp (408 t), mackerel (6951 t), *Hemirhamphus* spp. and *Belone* spp. (17 t), 'lesser sardines' (297 t) and 'other clupeids' (163 t). 'Total' has a quarterly average of 20,617 t. Thus a lower amplitude of mackerel in the figure is of far greater significance than the higher amplitude of *Hemirhamphus* spp. and *Belone* spp.

Explanations for such periodicities (Fig. 1) are perhaps to be sought in the environment and meteorological activity. Most fisheries, especially migratory ones like mackerel, are to a considerable extent guided by changes in the environment. Cyclical phenomena in meteorological elements in temperate latitudes have been reported by Ugryumov (1968). Investigations have shown that fish cycles are very closely related to meteorological activity. Lapin (1971) found that the curve of fluctuations in the abundance of pink salmon in the Amur Basin almost exactly repeats the curve of winter rainfal. Birman (1966, 1973) opines that in general, the two-year periodicity in the abundance of pink salmon changes at the time of greatest solar activity and in the southern most regions at the time of minimum solar activity. Thus Birman (1976) maintains that the two-year cycle in the abundance dynamics of pink salmon is caused by the quasi-biennial cycle of stratospheric winds, which in turn are caused by changes in solar activity. Dow (1977) found that most of the commercial marine and estuarine species of the coast of Maine are significantly correlated with sea temperature cycles. While admitting that the two-year cycle of pink salmon could be an adaptive self-adjustment to the two-year periodicity in reproductive conditions, and possibly also in the abundance of major food items for the young, Birman (1976) opines that regular rhythmic fluctuations in climatic conditions lie at the heart of fluctuations in abundance of most animal populations including fish.

The cyclical phenomena in the fish landings of the coast of Karnataka demonstrated in this study are of significance both to the fishermen as well as the conservationist and planner. The presence of a periodicity in the behaviour of fish landings, when there is no reason to expect any periodicity in the behaviour of the corresponding fishing effort, obviously reflects on the behaviour of the available fish stock itself. However, the causative factors can be short-listed only with more information on the hydrography, behaviour and biology of the concerned species/groups in relation to corresponding changes in the environment. It is important that these resources are studied as populations and not merely fisheries.

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