SEABIRDS AS INDICATORS OF IMPORTANT FISH POPULATIONS IN THE GULF OF CALIFORNIA

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ABSTRACT

We monitored the diet of the Heermann's gull (*Larus heermanni*) and the elegant tern (*Sterna elegans*) between 1983 and 1992 and compared the proportion of each fish species in the diet, through a correlation analysis, with the proportion of each of these same fish species in the commercial landings. We found strong positive correlations between the proportion of sardine (*Sardinops sagax caeruleus*) in the seabirds' diet and sardine landings. Strong negative correlations were found between the proportion of sardine in the seabirds' diet vs the proportion of anchovy (*Engraulis mordax*) in the birds' diet and anchovy landings. The proportion of sardine landings was negatively correlated with the proportion of anchovy in the seabirds' diet and with the proportion of the landings of both anchovy and mackerel (*Scomber japonicus*). The proportion of anchovy in the seabirds' diet was positively correlated with anchovy landings. A low, marginally positive correlation was found between the proportion of mackerel in the diet and the proportion of mackerel landed. Dietary studies of these seabirds provide reliable data on species composition of fish stocks, estimates of relative abundance, and availability of fish populations to higher trophic levels in this area. They also provide real-time, predictive, catch-independent data and complement commercial and research catch information.

RESUMEN

Entre 1983 y 1992 registramos la dieta de la gaviota ploma (*Larus heermanni*) y de la golondrina-marina elegante (*Sterna elegans*). Comparamos la proporción promedio de cada especie de pez en la dieta con la proporción de cada una de las mismas especies de pez en la descarga comercial por medio de un análisis de correlación. Se encontró una fuerte correlación positiva entre la proporción de sardina Monterrey (*Sardinops sagax caeruleus*) en la dieta y en la descarga comercial. Se encontraron fuertes correlaciones negativas entre la proporción de sardina en la dieta vs la proporción de anchoveta norteña (*Engraulis mordax*) en la dieta y en la descarga comercial. La proporción de sardina en la descarga comercial presentó una correlación negativa con la proporción de anchoveta en la dieta y con la descarga, tanto de anchoveta como de macarela (*Scomber japonicus*). La proporción de anchoveta en la dieta presentó una correlación positiva con la proporción en la descarga comercial. Se encontró una correlación baja y marginalmente significativa entre la proporción de macarela en la dieta y la desembarcada. Estos resultados indican que los estudios de la dieta de estas aves marinas proveen datos confiables acerca de la composición específica de la comunidad de pelágicos menores, así como estimaciones de la abundancia relativa y la disponibilidad de poblaciones de peces hacia otros niveles tróficos en esta región. Estos datos también proporcionan información en tiempo real y de valor predictivo que complementan la información obtenida por las capturas de la flota comercial y la exploratoria.

[Manuscript received February 4, 1994.]

INTRODUCTION

At a worldwide level, small pelagic fish (sardines, anchovies, etc.) represent a significant percentage of total fishery landings (25%). Numerous attempts to reach a sustainable use of these resources, and the equally numerous failures that have resulted in the collapse of many fisheries (Murphy 1981; Paulik 1983; Radovich 1982; Rothschild 1983) have evidenced the need for an ecosystemic approach to the analysis of these commercially important fish populations.

In Mexico, up to 1990, the landings of small pelagic fish represented 30% of the national total, 80% of which came from the Gulf of California. Species present in the catch were Pacific sardine (*Sardinops sagax caeruleus*), thread herring (*Opisthonema libertate*), Pacific mackerel (*Scomber japonicus*), round herring (*Etrumeus teres*), anchoveta (*Cetengraulis mysticetus*), and northern anchovy (*Engraulis mordax*) (Cisneros et al. 1991). The Gulf of California produced 70% of Mexico's commercial fishery, and Pacific sardine contributed 33% of the volume (Cisneros et al. 1991).

The Gulf of California is a subtropical sea with extremely complex hydrodynamics and a productivity comparable to the highest of any ocean, particularly in its northern portion (Alvarez-Borrego 1983). Strong upwelling, mainly of tidal origin, particularly in the Midriff Island region (figure 1), as well as a complex underwater topography are the principal factors that result in the

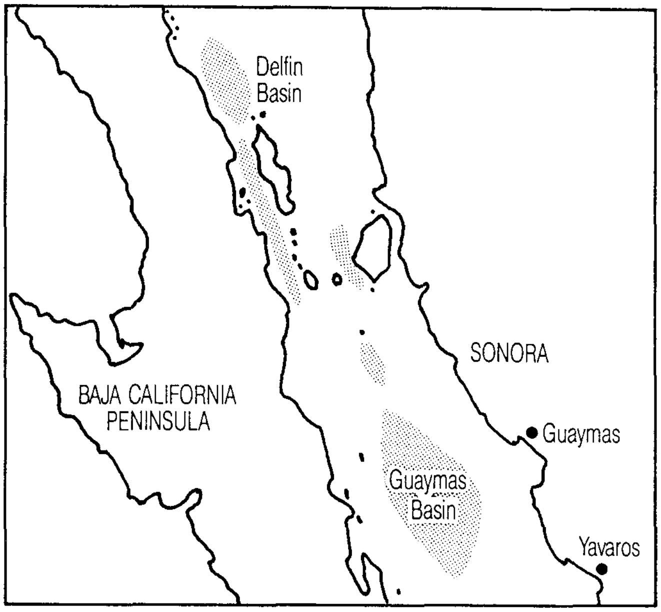

Figure 1. Section of the Gulf of California, showing the islands and the basins from the Midriff Island region to Conception Bay, Baja California, and the port of Yavaros, Sonora.

high productivity of the Gulf of California (Alvarez-Borrego 1983). Because of its high productivity and its geographic location in the border zone between the temperate and the tropical Pacific, the Gulf of California supports over half a million piscivorous seabirds. A large portion of the world population of several species breeds in the Gulf of California. For example, 99% of the world population of yellow-footed gull (*Larus livens*); 90% of Craveri's murrelet (*Synthliboramphus craveri*) and least petrel (*Oceanodroma microsoma*); 95% of Heerman's gull (*L. heermanni*) and elegant tern (*Sterna elegans*); and smaller but significant proportions (50%–70%) of other species, including the California brown pelican (*Pelecanus occidentalis*), blue-footed and brown boobies (*Sula nebouxii* and *S. leucogaster*), and black storm petrel (*Oceanodroma melania*) (Anderson 1983).

Until 1991, the Pacific sardine was the most abundant small pelagic fish in the gulf. This species is distributed along the Sonora and Baja California coasts, from the Guaymas and Carmen basins in the winter (Maluf 1983; figure 1), when the spawning peak occurs, to the Delfin Basin, where it migrates in summer (Cisneros et al. 1991; Hammann 1991; Hammann et al. 1991).

The northern anchovy, a species that has been recently reported to have occupied the Gulf of California, is restricted, like the Pacific sardine, to the low-temperature waters, mainly around the Midriff Islands (Cisneros et al. 1991). This species could have invaded the area as a consequence of a "La Niña" phenomenon during 1985 (Hammann and Cisneros-Mata 1989), but local fishermen believe that it has always been in the gulf, although in much lower abundances than at present. The northern anchovy population has increased steadily in recent years (Hammann et al. 1991).

Sardine catches by the fishing fleet in the Gulf of California from 1969 to 1990 increased at an average rate of 53% per year (estimated from data in Cisneros et al. 1991). Data from the Centro Regional de Investigación Pesquera of the Instituto Nacional de Pesca in Guaymas revealed that the Pacific sardine population of the Gulf of California began to show symptoms of overexploitation in the late 1980s: for example, a reduction in average size of individuals in the catches, and a smaller size at first reproduction (see Cisneros et al. 1990). These were the same signs shown by the Pacific sardine population when the northern anchovy began to replace it and before the sardine fishery collapsed in the California Current during the 1940s (Cisneros et al. 1990).

Generally, fish stocks are difficult to monitor; as a result, quick and wise management decisions are difficult to reach (Cushing 1988). Seabirds are valuable as sampling agents of the fish populations on which they feed (Ashmole and Ashmole 1967; Anderson et al. 1980, 1982; Sunada et al. 1981; Cairns 1987; Montevecchi et al. 1987; Montevecchi and Berruti 1991; Hamer et al. 1991). Their values are derived from the low cost of the sampling method, relative to the use of oceanographic research vessels, especially since seabird food studies can be combined with studies of breeding biology. The data obtained are catch-independent, complement commercial and research catch information, and provide real-time indices of relative abundance and availability of unsurveyed, commercially exploitable pelagic fish (Montevecchi and Berruti 1991).

The Heermann's gull and the elegant tern colonies in Isla Rasa total 240,000 and 45,000 birds, respectively (Velarde 1989; Tobón 1992). Their breeding season extends from late March to early July, and is both intra- and interspecifically synchronous, and constant from year to year (Velarde 1989; Tobón 1992).

In the Gulf of California, Heermann's gulls nesting in Isla Rasa were shown to be consuming mostly sardines during 1983 and 1984 (88.9% and 63.6% respectively; Velarde and Urrutia, unpublished data). In this paper we analyze the diets of two seabird species: the Heermann's gull and the elegant tern, and we compare the diet of these seabirds with the catches of small pelagic fish by the commercial fleet, in order to investigate potential correlations between them and to answer the following question: Do studies of the diets of seabirds feeding at certain areas and times of the year provide fishery-independent estimates on the species composition of fish stocks?

METHODS

The description of the diet of gulls and terns was made through the analysis of fresh regurgitations collected during the nesting season, from April through June, between 1983 and 1992 (except for 1987, a year in which data were not collected). Regurgitations were obtained from adult birds returning to the colony within a period of about three hours after dusk. Birds were captured with a mist net 9 m long by 2 m wide, with a 70 mm mesh. The net was placed 0.5 m above the ground and 200–300 m from the colony to avoid disturbing the nesting birds. In order to capture a substantial number of birds per sampling effort, the net was placed at a site where there was a relatively constant flux of birds going in and out of the colony.

Upon encountering the net and becoming entangled, most of the birds regurgitated the contents of their crop and, in the case of terns, also dropped the fish being carried in the bill for their chicks. Each regurgitation was placed in a plastic bag and assigned a number for subsequent reference. For each sample, the number of fish was estimated as the number of whole fish plus the number of heads or tails (whichever was greatest). Whole fish were numbered progressively within each sample. Whole fish and heads were identified to the species level whenever possible. The taxonomic determination was carried out with the help of field guides (Roedel 1948; Miller and Lea 1972; Thompson and McKibbin 1981) or through the examination of otoliths. When field determination was not possible, the sample was preserved in alcohol (30%) and identified with the help of specialists from the Centro Regional de Investigación Pesquera of the Instituto Nacional de Pesca in Guaymas, Sonora, and the Centro Interdisciplinario de Ciencias Marinas in La Paz, Baja California Sur. During 1983 and 1984, fish were identified only to the family level. For the purpose of comparison with samples from later years, Clupeoideae were assumed to be Pacific sardine, and Engraulidae to be northern anchovy, since no other Clupeoideae or Engraulidae species have been found in the seabirds' diet.

In April 1985, 1986, and 1989, when a high proportion of the samples were in an advanced state of digestion (because no chicks were hatched yet and food in the crop of the adult birds was only for the parent itself), only samples in a good state were used for the analysis.

Since most of the regurgitations contained only a single species of fish, the diet composition was determined through the frequency method, in which the number of regurgitations with a certain type of prey was divided by the total number that constituted the sample and was expressed as a percentage (Tordesillas 1992 and references therein).

Information on commercial catches of the species contained in the seabirds' diet, and landed in the ports of Guaymas and Yavaros, was obtained through the records kept and published by the National Fisheries Institute (Cisneros et al. 1991 and pers. comm.). These statistics were compared to those we obtained from the seabirds' diets. Yearly percentages of Pacific sardine, northern anchovy, and Pacific mackerel in commercial landings, in metric tons, were compared to yearly average proportions of these same species in the diet of seabird species studied by means of a Speerman rank correlation test (Zar 1974).

TABLE 1
Composition of the Diet of *Larus heermanni* and *Sterna elegans* in Isla Rasa, Baja California, Showing Sample Size (*N*) and Percentage of the Different Species

	Larus heermanni		*Sterna elegans*		Average
	N	%	*N*	%	%
1983					
Ss	43	97			97
Em	1	3			3
1984					
Ss	73	64			64
Em	42	36			36
1985					
Ss			10	31	31
Em			14	44	44
Sj			8	25	25
1986					
Ss			32	59	59
Em			19	35	35
O			3	6	6
1988					
Ss			49	54	54
Em			42	46	46
1989					
Ss	2	13	4	6	9
Em	13	87	67	94	91
1990					
Ss			1	2	1
Em	36	100	2	98	99
1991					
Em	90	98	110	96	97
O	2	2	5	4	2
1992					
Ss	1	2	5	9	6
Em	48	96	42	76	86
Sj			4	7	4
O	1	2	4	7	4

Ss = *Sardinops sagax*, Em = *Engraulis mordax*, Sj = *Scomber japonicus*, and O = others.

RESULTS

Annual use of small pelagic fish by seabirds is shown in table 1 and figure 2. Pacific sardine in the elegant tern's diet decreased abruptly between 1988 and 1989—from over 50% to 6%—and stayed under 10% thereafter. At the same time, northern anchovy increased from under 50% to almost 100%, staying over 75% thereafter. Pacific mackerel was fairly abundant (25%) in 1985 and disappeared thereafter until 1992, when it represented 7% of the diet.

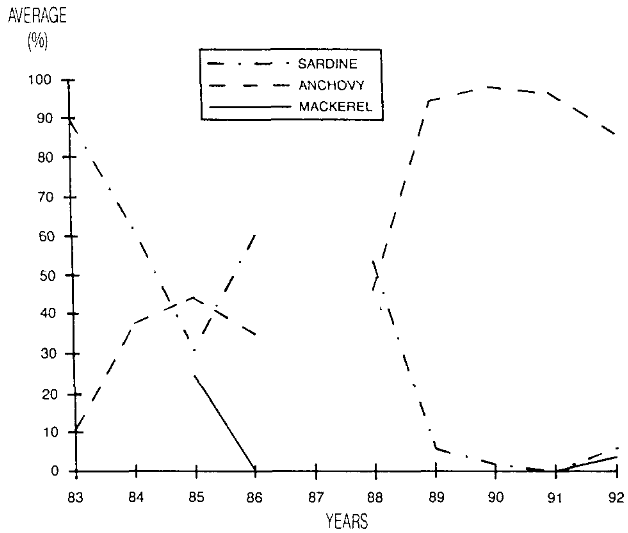

Figure 2. Yearly average percentage of three small pelagic fishes in the diet of seabirds in the Midriff Island region of the Gulf of California.

A similar pattern was apparent for the Heermann's gull. In 1983 Pacific sardine constituted almost 100% of the diet, and decreased steadily thereafter, disappearing completely in 1990. Anchovies increased in the gull's diet from under 37% before 1989 to 87% in 1989 (a change representing 50% of the diet), and over 95% thereafter (a change of almost 60% of the diet) (table 1).

Landings (and the percentage) of Pacific sardine, Pacific mackerel, and northern anchovy by the commercial fleet of the Gulf of California, in the ports of Guaymas and Yavaros, are shown in table 2. There was a positive correlation between the seabirds' relative consumption of sardines and their proportion in the catch (figure 3). Negative correlations were found between the proportion of sardine in the diet and the proportion of anchovies in both the seabirds' diet and the commercial landings. The proportion of sardine landings was negatively correlated with the proportion of anchovy in the seabirds' diet and with the landings of both anchovy and mackerel. Finally, the proportion of anchovy in the seabirds' diet was positively correlated with anchovy landings (figure 4). A low (R = .63) and marginal (P = .0562) correlation was found between the proportion of mackerel in the seabirds' diet and the proportion of mackerel landed by the commercial fleet (figure 5). Other correlations were low and/or not significant (table 3).

DISCUSSION

Many seabirds feed mainly on commercially important fish (Anderson et al. 1980, 1982; Sunada et al. 1981; Schaffner 1982). This is not surprising, since the typical shoaling distribution of small pelagic fishes, which renders them commercially exploitable, makes them easily exploitable to certain seabirds. This suggests a po-

TABLE 2
Percentage of Pacific Sardine, Northern Anchovy, and Pacific Mackerel Landed at Guaymas and Yavaros, Sonora, (from Cisneros et al. 1991) and Percentage of These Species in the Diet of the Seabirds

	Pacific sardine		Northern anchovy		Pacific mackerel	
Year	% Tons	% Diet	% Tons	% Diet	% Tons	% Diet
1983	99	97	0	3	1	0
1984	98	64	0	36	2	0
1985	93	31	0	44	7	25
1986	97	59	1	35	2	0
1988	99	54	0	46	1	0
1989	96	9	3	91	1	0
1990	77	1	13	99	10	0
1991	84	0	10	97	6	0
1992	28	6	22	86	50	4

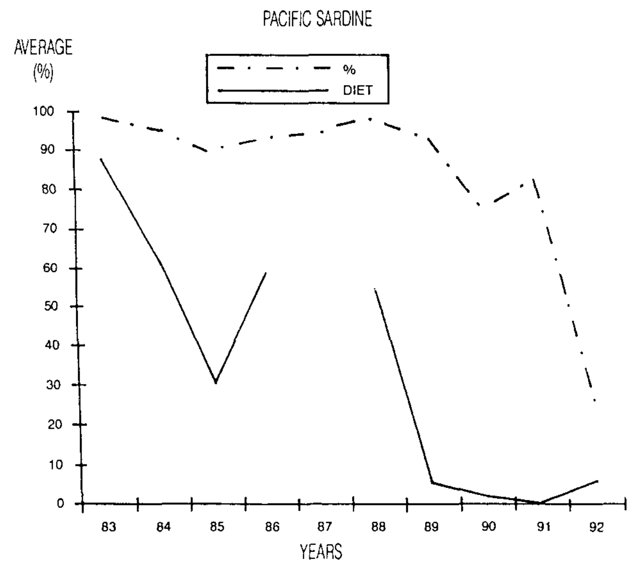

Figure 3. Percentage of Pacific sardine in commercial landings and in the diet of seabirds, 1983–92.

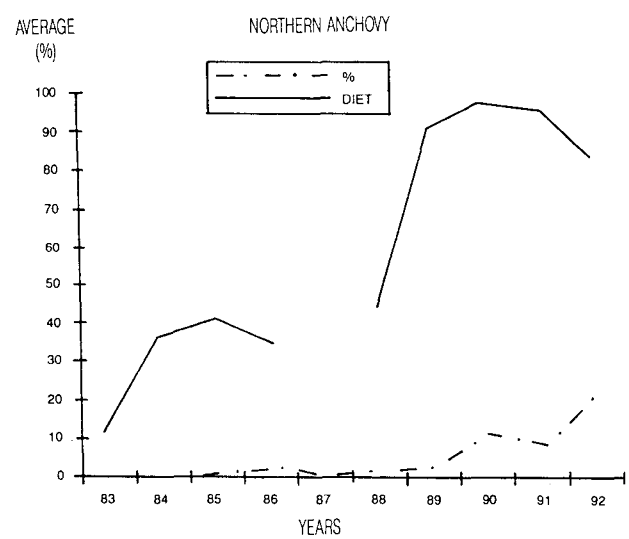

Figure 4. Percentage of northern anchovy in commercial landings and in the diet of seabirds, 1983–92.

TABLE 3
Results of Speerman Rank Correlation Analysis

		Pacific sardine		Northern anchovy		Pacific mackerel	
		Diet	Landing	Diet	Landing	Diet	Landing
Sardine diet	R =	——	.8452	−.9330	−.8008	−.1826	−.6044
	N =		(9)	(9)	(9)	(9)	(9)
	P =		.0168	.0083	.0235	.6056	.0874
Sardine landing			——	−.7029	−.8566	−.4813	−.8805
				(9)	(9)	(9)	(9)
				.0468	.0154	.1734	.0128
Anchovy diet				——	.7224	−.0228	.4341
					(9)	(9)	(9)
					.0410	.9485	.2195
Anchovy landing					——	.0834	.6268
						(9)	(9)
						.8135	.0662
Mackerel diet						——	.6061
							(9)
							.0865
Mackerel landing							——

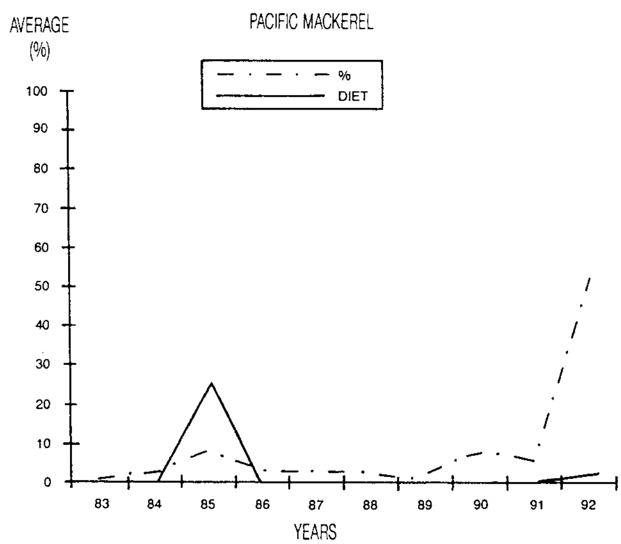

Figure 5. Percentage of Pacific mackerel in commercial landings and in the diet of seabirds, 1983–92.

tential competition between seabirds and fisheries for the same resource. In certain zones this relationship has temporarily benefitted fisheries, but has greatly diminished the seabird population. This has happened in Peru (Idyll 1973; Tovar 1978) and in South Africa (Crawford and Shelton 1978) among other places, where seabirds that specialized on a particular prey suffered reduced breeding success or did not breed at all (Cairns 1987; Hamer et al. 1991; Furness and Nettleship 1991). In the case of generalist-feeding seabird species, a change in prey stock may result in a change in diet (Montevecchi et al. 1987; Furness and Nettleship 1991).

The breeding season of most seabirds is markedly linked to seasonal fluctuations in the food supply (Perrins 1970; Kirkham and Morris 1979) and, during the nesting period, distribution and abundance of food are some of the most important factors that determine breeding success (Anderson et al. 1980, 1982; Cairns 1987; Hamer et al. 1991). Fisheries reports for the gulf (tables VIII and XI in Cisneros et al. 1991) indicate that Pacific sardines are most likely to be captured in the Midriff Island region between February and July. This coincides with the approximate time of the seabirds' nesting season in this area, indicating a likely coupling of the breeding season with the presence of the main food source.

The proportion of sardine in the seabirds' diets is positively correlated to total sardine landings in Sonora, and negatively correlated to proportion of anchovy in the diet and in the catch, showing that the first is a good indicator of the latter three. The proportion of anchovy in the seabirds' diets is negatively correlated to sardine landings and positively correlated to anchovy landings, which is expected from the above-mentioned correlations; it also shows that the first correlation is a good indicator of the latter two. Also expected from the above results is the negative correlation between sardine landings and anchovy landings. The negative correlations between the sardine landings and both the anchovy and the mackerel landings indicate that there is a tendency for the fleet to take these two latter species in the absence or reduction of the main target species, the Pacific sardine.

Whereas anchovy landings increased slowly but fairly steadily, at least until 1990, sardine landings suffered two distinct collapses: one in the 1989–90 fishing season and another in 1991–92 (figure 3). Landings were fairly stable between 1990 and 1991. An explanation for these observations may be that birds preferred anchovies over sardines, or that fishermen directed their effort toward sardines, and catches did not reflect the ongoing decline of the sardines.

As reported to the authors by fishermen, until 1989, most boats were equipped with sardine purse seine nets, and equipment in fishmeal factories was adapted for processing sardines, so fishing for and processing anchovies was avoided because of severe problems in handling the species (Doode 1992). Thus the fishing fleet avoided anchovy schools and actively searched for sardine, or else for schools of the larger mackerel, seldom catching a shoal of anchovies. This selective fishing for sardines created a proportionately larger pressure on the dwindling sardine population; this pressure was sustained for two seasons: 1989 through 1991. More opportunistic foragers—gulls and terns—most likely fed on pelagic fish according to their relative proportions in the environment. The proportion of sardines in the seabirds' diets was negatively correlated both to anchovy in the diet and anchovy landings, as would be expected from a more opportunistic or random process, the species composition being less biased in the diet.

Also evident from the data (figures 3–5) is the fact that birds detected changes in the composition of the small pelagic fish community in a more pronounced way and, sometimes, at an earlier date. For the sardine, for example, a reduction in the seabirds' diet of almost 70% in 1985 was reflected in only a less than 10% reduction in the catch, whereas a major reduction in the seabirds' consumption of sardine in 1989 was reflected by a similar reduction in the catch only in 1992, a three-year lag.

In the case of the anchovy, a 30–40% increase in the seabirds' diet, peaking in 1985, was reflected by a 5% increase in the catch, peaking in 1986. Furthermore, the anchovy landings do not surpass 10% of the total small pelagic fish landings until 1990, six years after this species had reached over 30% in the seabirds' diet, in 1984.

For mackerel, an almost 50% increase of consumption by the seabirds was reflected by a catch increase of less than 10% in 1985. However, this does not hold for this species after 1989, when a 7% increase in the diet was reflected by a 50% increase in the catch. This may be due to the lack of the main target species for fisheries—the Pacific sardine—and to the fact that mackerel are preferred by fishermen over anchovies because anchovies create some problems both during capture and during processing for reduction. Furthermore, anchovies are not suitable for canning.

In conclusion, studies of the diets of these seabirds provide useful data on the species composition of fish stocks in the area studied, and probably provide a more reliable index of changes in forage-fish populations than do data derived from commercial landings. Evidently, Heermann's gulls and elegant terns, among other seabirds (Anderson 1983; Velarde and Anderson, in press), have coupled their breeding season with food availability in their nesting area (Cisneros et al. 1991; Hammann et al. 1991; Velarde et al., in press). This coincidence in time and space makes these seabirds valuable sampling agents and indicators of food supply within their foraging range during the nesting season. These birds sample small pelagic fish at precisely the time when both juvenile and adult populations of several species of the fish arrive at the Midriff Island region (Cisneros et al. 1991; Hammann 1991; Hammann et al. 1991). Therefore, these seabirds constitute useful indicators of ecological changes related to their food source, such as the succession or alternation of small pelagic fish species in the ecosystem.

ACKNOWLEDGMENTS

Through the years, field work has been supported by Instituto de Biologia–Universidad Nacional Autónoma de México, Consejo Nacional de Ciencia y Tecnologia, the Mexican Navy, Agrupación Sierra Madre, World Wildlife Fund, The Nature Conservancy–International Program, International Council for Bird Preservation, and Cementos Mexicanos. We thank the Dirección General de Conservación Ecológica de los Recursos Naturales from the Secretaria de Desarrollo Urbano y Ecología for granting the permits for field work in the Reserve of Isla Rasa. We acknowledge H. Montiel, Director of the Centro Regional de Investigación Pesquera in Guaymas, for his constant interest and support, as well as all the people in that institution involved in the Programa de Pelágicos Menores. We thank M. I. Ramirez for her advice and help with the data analysis. We are grateful to D. W. Anderson, M. A. Cisneros, G. Hamman, G. T. Hemingway, and two anonymous reviewers for the valuable critical review of the manuscript.

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