BROWN PELICANS AS ANCHOVY STOCK INDICATORS AND THEIR RELATIONSHIPS TO COMMERCIAL FISHING

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ABSTRACT

Seabirds as offshore wildlife resources have largely been unstudied by wildlife managers until recently. Brown pelicans (*Pelecanus occidentalis californicus*) in Southern California Bight (SCB) have received special attention in the past under the Endangered Species Act of 1973 (ESA). Special consideration is given to species with endangered status in commercial fishery management plans mandated by the Fisheries Conservation and Management Act of 1976, but such plans also attempt to deal positively with all species of seabirds and marine wildlife as society's values change more positively toward such offshore wildlife resources.

Brown pelican breeding status is heavily dependent on abundance and/or availablility of anchovies during the prebreeding and breeding periods. This is likely due to the dominance of northern anchovy (*Engraulis mordax*) biomass in surface schooling fishery stocks in the SCB. The predator-prey relationship that involves brown pelicans and anchovies in the SCB is a tenuous one due to 1) the strong dependence almost solely on anchovies evidenced over the last nine years of study and 2) potential increases of commercial harvest of anchovies since 1979 under some options of the Anchovy Management Plan provided by the Pacific Fishery Management Council. There are also two elements of this interaction that complicate straightforward management of pelicans: a) implementation of a liberal harvest option under the Anchovy Management Plan rather than a more conservative one and b) increasing anchovy harvests in Mexico. Unless anchovies are replaced by another prey, breeding pelicans may ultimately require a larger forage reserve of anchovies, offshore refuges (critical habitat under the ESA), and possibly more conservative quotas in the anchovy reduction fishery. A management plan for brown pelicans and other seabirds in the SCB has not yet been developed by the appropriate agencies.

Past anchovy harvests (pre-1979) probably did not detectably disrupt the pelican/anchovy relationship, although at the higher observed levels of pelican reproduction (coincident with higher levels of anchovy biomass and catch), pelican reproductive rate was not maximal. This is more likely because pollution may still be chronically affecting pelican reproduction. Anchovy harvests under an optimum yield scheme will be monitored closely for possible effects on pelican reproduction. Although more detailed studies are needed, we provide some initial suggestions based on brown pelican requirements.

RESUMEN

El estudio de las aves marinas como recursos faunísticos en las zonas lejos de la costa ha sido bastante desatenido hasta fecha reciente por los organismos encargados de la fauna silvestre. Los pelícanos gris (*Pelecanus occidentalis californicus*) de la Bahía del Sur de California han recibido atención especial con el Endangered Species Act (ESA) de 1973. En los planes de administración de la pesquería comercial incluídos en el Fisheries Conservation and Management Act de 1976, se ha prestado atención especial a especies en peligro de desaparición, pero esos planes también intentan abarcar todas las especies de aves marinas y de vida marina a medida que cambian más los valores que la sociedad atribuye a esos recursos de los animales salvajes oceánicos.

El pelícano gris depende básicamente de la abundancia y/o disponibilidad de anchoveta durante los períodos de precrianza y crianza. Probablemente ésto se debe a que la biomasa de anchoveta del norte (*Engraulis mordax*) es dominante en los cardúmenes de la Bahía del Sur de California. La relación predador-presa entre el pelícano gris y la anchoveta en la Bahía del Sur de California es débil a causa de 1) su casi exclusiva dependencia sobre la anchoveta, según se evidencia en los últimos nueve años de estudio, y 2) incrementos en la captura comercial de anchovetas desde 1979 bajo algunas opciones del Anchovy Management Plan según las provisiones del Pacific Fishery Management Council. En esta interacción hay también dos elementos que complican la administración directa de pelícanos: a) la implantación de una opción de pesca amplia bajo el plan de administración de la pesquería de anchovetas, en lugar de una más conservadora, y b) el incremento de pesca de anchoveta en México. A menos que se reemplacen las anchovetas con otra presa, los pelícanos en estado de crianza podrían requerir una reserva más grande de alimento de anchovetas, refugios fuera de la costa (hábitat crítico bajo el ESA), y posiblemente cuotas más conservadoras reduciendo la pesquería de anchoveta. Las agencias responsables no han desarrollado todavía un plan para la conservación de los pelícanos gris y otras aves de la Bahía del Sur de California.

La pesquería de anchoveta anterior a 1979 probablemente no afectó notablemente la relación pelícano/anchoveta, aunque se ha observado que a niveles elevados de reproducción del pelícano (que coinciden con niveles más

elevados de captura y biomasa de anchoveta), el índice reproductor del pelícano no alcanzó un máximo. Probablemente se debe a que la contaminación puede estar aún afectando crónicamente la reproducción del pelícano. La pesca de anchoveta bajo un esquema de rendimiento óptimo será cuidadosamente inspeccionada para determinar posibles efectos sobre la reproducción del pelícano. Aunque se necesitan estudios más detallados, proveemos algunas sugerencias iniciales basadas en los requisitos del pelícano gris.

INTRODUCTION

As wildlife values change in our society, the chances for socioeconomic conflict increase. This will be especially true where commercially harvested resources might relate in some way to æsthetic or noncommerial ones, especially through conflicts in different value systems (see Langford and Cocheba 1978; Bart et al. 1979; and others). In the past, seabirds and other marine wildlife were viewed as undesirable competitors. Marine birds, a "neglected" resource in North America until recently (Bartonek and Sowl 1974), are often dependent on commercially utilized resources, and only recently are they being viewed by wildlife managers as valuable, conservable, and manageable resources in themselves (see Cline et al. 1979; Nisbet 1979; and this symposium). The alternative approach of using seabird population parameters as indices to aid the monitoring of commercially valuable fishery stocks is a technique with much potential in providing added, independent input for fishery managers.

Some seabirds such as the California brown pelican (*Pelecanus occidentalis californicus*), and its habitat, are given special protection under the Endangered Species Act of 1973 (ESA); this act enables the various management agencies to cooperate on the management of offshore ecosystems.

The collapse of the anchoveta (*Engraulis ringens*) fishery in Peru (Clark 1977) and associated detrimental effects on seabirds, both before the collapse (intentional and predicted population reductions of seabirds due to heavy fishing activities; Schaefer 1970; Paulik 1971) and after the collapse (Idyll 1973), are well-known. Related events occurred in the South African pilchard (*Sardinops ocellata*) fishery (Cram 1977), with well-demonstrated negative interactions between intensive commercial fishing activities and seabird populations (Frost et al. 1976; Crawford and Shelton 1978; Cooper 1978). There is also concern that increased krill (*Euphausia superba*) harvests will detrimentally affect marine wildlife in Antarctica (Beddington and Lawton 1978; May et al. 1979).

Fortunately in the Southern California Bight (SCB), through the Fishery Conservation and Management Act of 1976, there is an optimum yield management plan (Pacific Fishery Management Council [PFMC] 1978; see Radovich 1979, Radovich and MacCall 1979, MacCall 1980 for further details and discussion) that will ideally insure that northern anchovies (*Engraulis mordax*) will not be overfished. Several potential problems exist, however, off southern California that might affect anchovy predators, in this case namely the brown pelican: 1) increasing Mexican harvests of anchovies (Chavez et al. 1977) and 2) increased harvests off southern California under a liberal option provided in the Anchovy Management plan (PFMC 1978; McCall 1980).

Values of offshore wildlife and the needs of those resources further complicate a management situation in the SCB that May et al. (1979) have summarized as such: "This is a particularly clear example of a complex situation where biology, economics, and politics roil together, and it is doubtful whether any 'scientific' principles of management are particularly relevant." We are not so sure that the situation here is as hopeless as might be implied; and in fact, we believe that the potential for interdisciplinary and interagency collaboration in the SCB area is great. Here we intend to approach this situation from the viewpoint of one local population of seabird: brown pelicans nesting on islands off southern California.

PELICAN DEPENDENCE ON AND RELATIONSHIPS TO ANCHOVIES

Keeping in mind that we are here referring to breeding populations and productivity of SCB brown pelicans only (not migrants), previous research (Anderson et al. in preparation, Gress et al. in preparation) has established that:

1) There are only two major brown pelican nesting colonies in the SCB, Anacapa Island (and associated Scorpion Rock) and Isla Coronado Norte just across the Mexican border. On occasion, pelicans have also nested on such islands as Santa Barbara, Prince, and others (Gress 1970).

2) Pelican breeding effort at both colonies (numbers of pairs that attempt to breed each year) is probably dependent largely on regional levels of anchovy abundance, but this relationship is difficult to document without total population censuses of pelicans.

3) Pelican reproductive rate (fledging success = F) depends largely on levels of anchovy abundance and availability. The diet of breeding pelicans from 1972-79 was comprised of 92% anchovies ($N = 2195$; Gress et al. in preparation). At Anacapa Island, breeding pelicans feed mostly in the Santa Barbara Channel later in the breeding season, but their feeding areas are variable due to mobility of their prey, anchovies (Gress et al. in preparation). Less is known of pelicans nesting at Coronado Norte, but a similar situation involving feeding areas is likely.

4) Anchovy availability in the local situation is

usually, but not always, related to overall abundance in the SCB.

5) Past complications from pollution in the SCB disrupted the above pelican/anchovy relationships until about 1972. Therefore, the situation as we know it today is recent. The major source of DDT in pelicans was contaminated anchovies, but both pelicans and anchovies have shown significant declines in DDT-related pollutants since 1972. Present pelican recruitment is still bolstered by young pelicans produced at colonies in southern Baja California or the Gulf of California. Productivity in the SCB is still most likely depressed due to residual pollutants (Anderson et al. 1975, 1977), but this is difficult to evaluate in comparison to the acute problems observed earlier.

6) Past Pelican breeding populations in the SCB probably had a larger prey base than they do today, perhaps also importantly involving Pacific sardines (*Sardinops caerulea*) and Pacific mackerel (*Scomber japonicus*; see Anderson and Anderson 1976). Pacific mackerel populations in the SCB have recovered considerably since 1978 (J. Radovich, personal communication), but this formerly abundant fish species was not a significant prey item of breeding brown pelicans in 1978 and 1979 (Gress et al. in preparation). Preliminary results of recent pelican food habit studies suggest, however, that Pacific mackerel was a more common forage item in 1980.

The "simplified" situation makes pelicans (and other predators dependent on anchovies) all the more sensitive to changes in these fish due a) to environmental stochasticity and its associated variation in anchovy carrying capacity (MacCall 1980) and b) to reduced carrying capacity for pelicans through increased anchovy harvests. Of course, the only variable that managers can manipulate or control is b).

We envision the prey (anchovy) situation as varying from widespread abundance and availability to only local availability (see PFMC 1978). In both situations pelicans can reproduce above the long-term mean if availability occurs near the breeding colonies long enough to sustain a complete reproductive season; but they do best when total anchovy biomass is high over the entire SCB. For pelicans, a complete reproductive season amounts to about 4½ months (Anderson et al. in preparation; Schreiber 1980). Pelicans are also restricted to a timely breeding season, especially in the later phases, partly due to the energetic and nutritional constraints of molt (D.W. Anderson unpublished).

For the purposes of our discussions here, we will emphasize one very important pelican/anchovy relationship: mean SCB anchovy biomass and mean pelican reproductive rate in the SCB (Figure 1). We cannot review all pelican reproductive parameters that are responsive to anchovy abundance (total biomass of nonlarval fish in the SCB) or availability (total biomass of catchable fish). In fact, our field studies are just beginning to yield fruitful insights from our long-term data base; and they continue, especially now that harvests of anchovies are likely to change. Productivity ($= F =$ fledging rate $=$ number of young produced to flying age per nest attempt) is one of the most sensitive reproductive parameters of brown pelicans as an index to anchovy availability (Anderson et al. in preparation). Therefore, we will stress F in this discussion. Actually, F is probably a better index of local food supplies, but because of the usual relationship to regional abundance and the large cruising range of feeding pelicans (D.W. Anderson unpublished data), it provides a valuable starting point.

One thing is certain: SCB's brown pelicans definitely reproduce best during periods of high anchovy abundance (Figure 1), or in rarer cases, as in 1979 at Anacapa Island[1], when anchovies were locally abundant (Gress et al. in preparation). It is interesting that also during another period of high anchovy abundance, the mid-1960's (see Stauffer 1980), brown pelican population indices were also high (see Anderson and Anderson 1976).

The year of greatest disparity, 1973, needs to be mentioned at this point. The data from 1973 should be excluded from our calculations (Figures 1 and 3) because of unusually large numbers of migrant pelicans in the SCB during the resident breeding season that probably interfered with the resident breeding effort that year (Anderson et al. in preparation for detailed discussion). Therefore, normal predator/prey relationships were perhaps clouded by unusual behavioral phenomena.

But for the skeptic, we here present data both with 1973 (w/73) and without it (w/o 73). Exclusion of 1973 does not change our conclusions, but it gives more precise data fits for our predictions. Ignoring the behavioral phenomenon of 1973, or accepting it as one element of stochasticity in a more idealized relationship, we have then examined one important pelican reproductive parameter against an index of SCB anchovy biomass. It is important to do so because management for the central stock of anchovies is put on a similar large-scale geographical basis (PFMC 1978; Radovich and MacCall 1979; MacCall 1980).

We hope to illustrate how brown pelicans might act as useful indicator species to provide fishery managers an added basis for estimating "forage reserve" (PFMC 1978) for pelagic consumers. Hopefully, our long-term

[1]The brown pelican breeding effort on Anacapa Island in 1979 was unusual in that the period of egg-laying extended over a six-month period (from 1970 to 1978 the range was 2.0 to 3.75 months). Moreover, the number of nesting attempts ($n = 1{,}258$) and number of young fledged ($n = 980$; 0.78 young fledged/nest attempt) from the Anacapa Island colony was greater than in any year since continuous studies begain in 1969 (Gress et al. in preparation). Although overall anchovy biomass was low in the SCB in 1979, a local abundance comprised primarily of juveniles was concentrated in the Santa Barbara Channel just north of Anacapa and Santa Cruz Islands (Mais 1979). These anchovies were for the most part too small to harvest but were apparently of sufficient abundance to support a greatly expanded pelican breeding effort.

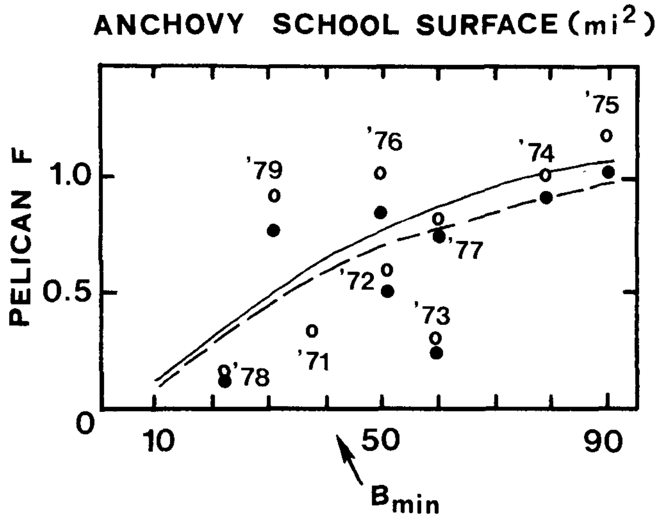

Figure 1. Relationships between brown pelican fledging rates (F = young fledged per nest attempt) at Anacapa Island (closed circles) and Isla Coronado Norte (open circles) and indices of general anchovy abundance (B) in the Southern California Bight. The dashed line is the regression with the 1973 data included, and the solid line is with 1973 data excluded (see text for explanation). Anacapa Island for 1971 is not plotted because severe DDT effects were still evident there (see Anderson et al. 1977). B_{min} represents minimum anchovy biomass for effective pelican reproduction under average conditions. The 1979 anchovy school surface area indices were projected from biomass estimates of Stauffer and Parker (1980) and Stauffer (1980) because budgetary restrictions prevented comparative data via the acoustic surveys (Mais 1974, manuscript).

data represent optimum parameters under the current set of SCB conditions, although we know that local SCB pelican reproduction is still too low for population stability (Anderson et al 1975, 1977, in preparation).

An index to anchovy abundance (B) is expressed in one way by Mais (1974) as mi^2 of anchovy schools in a constant sample zone of the SCB. We have related this index to pelican reproduction. The best fit for the F versus B relationship is found to be in the form of the logarithmic curve, $F = a + b \ln B$ (Figure 1):

(w/73); $n = 17$, $r = 0.62$, $F = -1.2 + 0.48 \ln B$,

(w/o 73); $n = 15$, $r = 0.80$, $F = -1.4 + 0.55 \ln B$,

where n equals the number of data points and r equals the correlation coefficient.

It appears that the curve breaks at about $B = 40$ mi^2 (denoted as B_{min} on Figure 1). This break is defined on the basis of the long-term mean pelican fledging rate (F) of about 0.6; however, this is probably not sufficient for population maintenance in the SCB. But it represents an estimate of the present situation in the SCB as complicated still by pollution. First, we are assuming that B_{min} represents, under SCB conditions, minimum levels of anchovy abundance for effective pelican reproduction. The zero deviation level from the long-term mean of F represents B_{min}, as well. That level of food in terms of anchovies is as follows (where Dev. B is the deviation from its long-term mean):

(w/73); $r = 0.62$, Dev. $F = 1.1 + 0.71 \ln$ Dev. B, and

(w/o 73); $r = 0.75$, Dev. $F = 1.2 + 0.82 \ln$ Dev. B;

(w/73); 0 deviation (pelicans) = 41 mi^2,

(w/o 73); 0 deviation (pelicans) = 46 mi^2.

Therefore, it appears (Figure 1) that a total biomass level of roughly 43 mi^2 (by acoustical survey, or = about 2.15×10^6 short tons using an extension based on 1978 comparative data from Stauffer and Parker (1980) might represent a level in the SCB below which pelican reproduction is very poor. This forage reserve estimate of 2.15 million short tons represents about 78% of the long-term mean of 2.75 million short tons of biomass estimated for the central stock of anchovies (MacCall 1980). That spawning biomass might be a minimum goal for wildlife needs, assuming that the brown pelican is a suitable and representative indicator species. Our estimate is, however, almost twice the forage reserve recommended in the Anchovy Management Plan (PFMC 1978), but at this point must also be regarded as an estimate. Certainly we need a more accurate measurement of pelican (wildlife) needs relative to anchovy biomass, availability, and behavior of prey and a better estimate as to how such relationships between pelicans and anchovies are applicable to other wildlife species.

PELICANS AND COMMERCIAL ANCHOVY FISHERIES

Catch statistics represent a confusing mixture of biological, political, and regulatory phenomena. Here we use catch data only for the period when pelicans would be expected to be breeding to enable further comparisons that might shed some light on the seabird/fisherman interaction. A good argument might be made for the premise that commercial anchovy catches of the past had little or no effect on pelicans for the period where data on pelicans are available (1972-78; Figure 2). MacCall (1980) has suggested that the existing, small fishery of the SCB apparently did not affect the large variance in anchovy biomass previous to 1979. A logical extension of this would be that both pelicans and fishermen responded to variations in anchovy biomass for both consumers without mutual intereference (Figure 2). Because of this, one could argue that, although perhaps arbitrary (PFMC 1978; probably because CDFG was responding to political pressures from sportsmen; see Kaneen 1977, May et al. 1979), the previous establishment of quotas and the resulting catches were somewhat in pace with anchovy stocks and pelicans.

When plotted with an equation of the same logarithmic form as above, it appears that the old fishery outpaced pelicans in response at the higher levels of anchovy abundance (Figure 3). Such a relationship can be interpreted

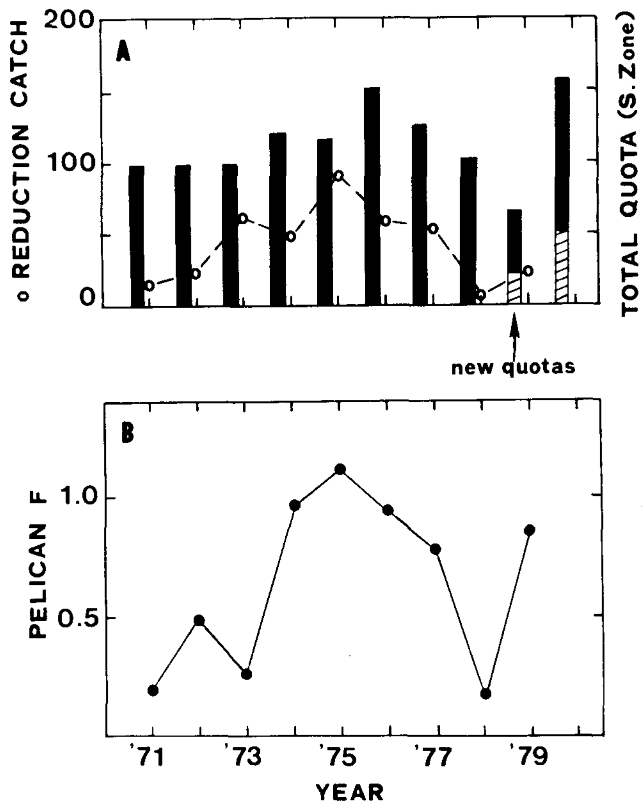

Figure 2. A. Anchovy catches (open circles) during the pelican breeding seasons (February through May only) superimposed on the various anchovy catch quotas (bar graphs) from 1971 through 1979. This does not represent the entire catch (see PFMC 1978 for those data). Catch and quota data are expressed as tons × 10³. B. Pelican reproductive rates (=F= young fledged per nest attempt) at Anacapa and Coronado Norte Islands combined (closed circles). The 1979 bar graph represents the start of a new cuota system for the harvest of anchovies, and the hatched portions of the 1979 and 1980 quotas represent a more conservative option for harvest under the same Anchovy Management Plan (PFMC 1978; Radovich and MacCall 1979; MacCall 1980). The 1979 increase in pelican productivity was due to locally abundant concentrations of 1978 year-class anchovies near the breeding colonies (Gress et al. in preparation). Southern zone (SCB) quota data are from Kaneen (1977), PFMC (1978), Stauffer and Parker (1980), and Stauffer (1980). Under the new system, only U.S. quotas are shown, and they comprise about 70% of calculated optimum yield (Stauffer 1980). A fall catch for 1979 of 5,810 tons was the lowest in recent years (K.F.M.)

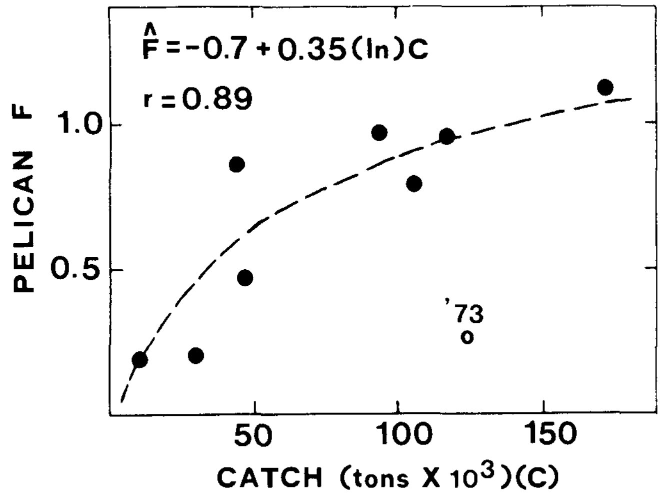

Figure 3. Anchovy reduction catch (fishing activities) versus pelican productivity (fledging rate) in the Southern California Bight from 1971 through 1979. See text and Anderson et al. (in preparation) for explanation of anomalous conditions in 1973 (1972-73 breeding season).

in several ways:

1) Both predators (man and birds) are limited by their own asymptotic rates, but the birds approach it somewhat sooner. Reproductive output in pelicans undoubtedly has an upper psysiological limit in this K-selected species due to the constraints of genetically-fixed upper clutch size (which is in turn determined largely by the number of young the parents can effectively feed; Lack 1954). Maximum clutch size in pelicans is very close to three (Anderson and Hickey 1970) but almost never exceeds three.

2) The two predators respond to aspects of fish behavior which differentially change with fish abundance. Density-dependent behavioral changes might occur in the prey: a) At very high densities, schools of anchovies may become larger and proportionately more resistant to predation by brown pelicans and other natural predators (review by Radovich 1979). Conversely, at very high densities, anchovies may be more vunerable to purse-seining. b) At the higher biomasses in the SCB, fish may disperse into areas where they are less likely to be found when at lower biomasses. Local carrying capacity (K) for pelican food may be at a maximum, although total biomass may increase. In either case, prey would continue to be vulnerable to fishing by man, but vulnerability to natural predation may decrease (Clark 1974).

3) There may be direct competition between boats and birds, with boats being the controlling or more effective competitor. There might actually be a biomass or availability decline at the higher fishing levels that interferes with further increases in K for pelicans, i.e. fishing becomes more competitive with natural predators. This would be likely in the heavy fishing regime such as the Peruvian example cited previously. Because pelican F versus biomass from SCB's previous fishery takes the same form (Figure 1 versus Figure 3), this is the least likely explanation in our example.

4) A.D. MacCall (personal communications) has proposed a fourth hypothesis: There may be less of a differential response than is apparent from the available data. Fishermen may have varied fishing effort according to its profitability. Fish prices increased in the mid-1970's due to the collapse of the Peruvian fishery (Clark 1977), but fuel costs increased in the late-1970's. This aspect deserves study.

All of the above might operate, or various combinations of them. At this point, we cannot say what has actually happened. It should prove very interesting to monitor this relationship under the increased quotas of the new Anchovy Management Plan.

PELICAN FEEDING ZONES

Anacapa Island is the only regular brown pelican breeding colony in U.S. waters of the SCB, and our most intensive research has been conducted there. At Anacapa, pelicans feed mostly in the Santa Barbara Channel during the later phases of the breeding season but in essence wherever the fish are earlier (Gress et al. in preparation). Important anchovy catches could also come from those areas (PFMC 1978; see also Chavez et al. 1977). Such areas (and equivalent areas also at Coronado Norte as yet undefined) are perhaps where the most significant pelican/fisherman overlap might occur. But, because of the unpredictable nature of the prey, these areas may not be definable from season to season or even within seasons. When plotted by California Department of Fish and Game statistical blocks, it does not appear that anchovy harvests near Anacapa have contributed a major portion of the total catch (Figure 4). Equivalent data are not available for Los Coronados. Loss of the area near Anacapa to fishing would amount to a loss of about 15 to 20% of California's SCB anchovy fishing waters. Since brown pelicans, like other seabirds, are most sensitive to local food supplies during the breeding period involving the raising of young (Ashmole 1971), the establishment of local feeding areas may be one important management strategy, particularly until better quantitative data are available. Such zones are in need of more accurate definition, but the studies of Briggs et al. (1980) suggest that near-colony refuge areas might encompass waters of 40 fathoms or less.

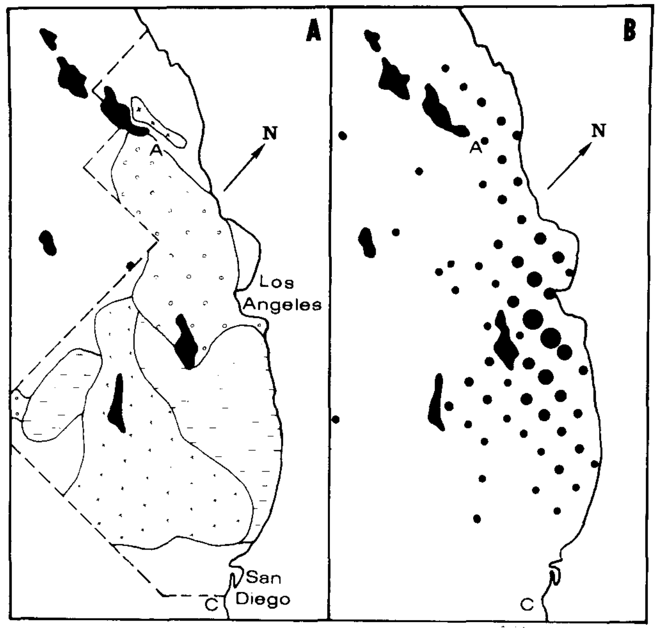

Figure 4. A. Anchovy biomass distribution from cruise 77-A-3 (K.F.M.), roughly showing typical relative densities of anchovies during the pelican breeding season. Abundance in this case was low compared to previous years. This figure was selected from a larger series of recent surveys as representative of one of many variable anchovy distribution patterns. The x's represent high relative densities, open circles moderate, dashes low, and blank spaces very low or negligible values. The letter "A" shows the location of Anacapa Island (including Scorpion Rock) and the letter "C," Islas Coronados. Major offshore islands are shown in black. B. Total anchovy reduction catches by California Department of Fish and Game block for 1972 through 1977 (catch in 1978 was nearly nil) in the Southern California Bight during the brown pelican breeding period (February through May). Increasing sizes (5 sizes) of circles indicate increased catches in the 10-minute blocks as follows (lbs × 10^6): <1,000, 1-5,000, 5-25,000, 25-75,000, and >75,000. In August 1973 and 1974, there were also 2,672 × 10^6 and 221 lbs × 10^6 of anchovies taken, respectively, very near Anacapa Island. Due to a consistent, but unavoidable, failure of three boats operating near Anacapa Island to report exact areas of catch by block, the catches for all those blocks surrounding Anacapa should be increased by about 20% to more accurately reflect effort there (K.F.M.).

GENERAL DISCUSSION AND CONCLUSIONS

We believe that potential interaction between brown pelicans and newly adopted commercial fishing quotas for anchovies represents a challenge for wildlife and fisheries managers alike. Of course we can only predict what might happen and can never know for sure until pelicans have been monitored for many years under such a regime. MacCall (1974), Radovich (1979), and others have urged careful expansion of the southern California anchovy fishery in light of multiple uses of this resource. We think the management and conservation needs of offshore wildlife such as brown pelicans add a new dimension to the goals of management of commercially valuable resources such as anchovies. The PFMC Anchovy Management Plan already provides viable harvest options that can be altered or chosen to best fit the needs of multiple use.

The dependency of brown pelicans on anchovies under present conditions is well demonstrated, but more quantitative data are needed for recommendations on management specifics. Tentatively, it appears that a larger forage reserve is needed. Regarding production of brown pelicans, and likely other avian piscivores in the SCB, it seems that the most effective management will occur when anchovy populations are maintained above B_{min}.

Even from the limited data presented here, it is suggested that some brown pelican feeding zones (critical habitat by the ESA) need to be defined soon. Refuges and closed areas should be established by the management agencies to minimize adverse wildlife and commercial fishery interactions.

A crude estimate of forage requirements (even assuming total anchovy diet) indicates that pelicans, as only one of many potential predators, consume negligible proportions of total anchovy biomass. Assuming a mean resident pelican population of 6,000 SCB birds (see Briggs et al. 1980), a food requirement of about 2 lbs/day (Anderson unpublished data), 2,000 breeders producing 900 young each year at 150 lbs/young (see Schreiber 1976), only 0.08% of the mean SCB anchovy biomass of 2.75 million short tons (MacCall 1980), or about 2,260 short tons/year (including 67.5 short to produce young) is required. With migrant pelicans added in the fall period (Anderson and Anderson 1976) and assumed to be about 75,000 birds for a mean period of three months (Briggs et al. 1980), this requirement increases to only 0.33%, or about 9,000 short tons. However, the conditions of the food-base resource would seem to strongly dictate the status of pelican populations, for the birds require a much larger population size to produce availability levels such that this ration can actually consumed.

Several fishing management promoters may therefore need reexamination as seen by the brown pelican; and in the least, we hope that we have stimulated enough interest to further necessary studies, and with more species of seabirds. Seabirds represent a potential tool to fishery managers besides being valuable resources in themselves. Fishery managers in the SCB have requested that wildlife managers provide them added input, and we hope that a start has been made here, although perhaps meagre.

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