Salton Sea Christmas Bird Count Data Analysis

Trend analysis of bird populations and number of bird species at the Salton Sea from 1969 to 1998

By Shuzo Yoshihara
Math Consulting Lab, Fall 1999
University of Redlands

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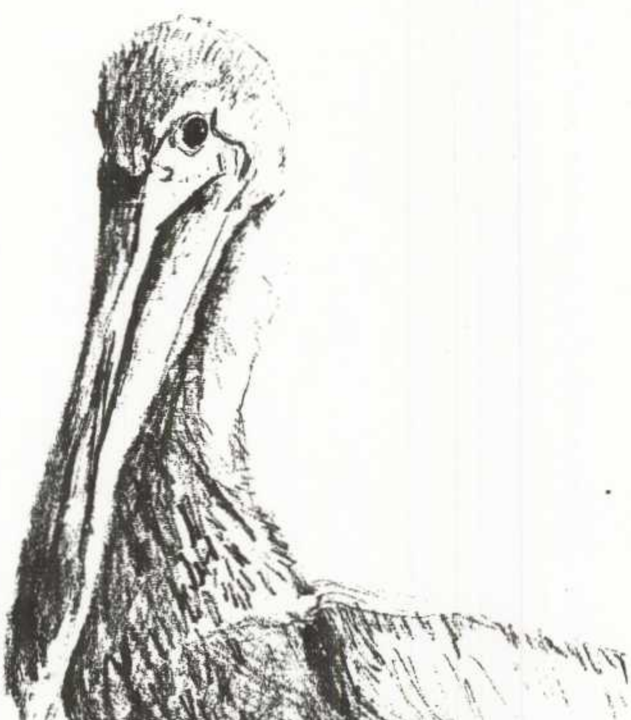

Christmas Bird Count Data

1.0 Purpose

The objective of this report is to show the ecological importance of the Salton Sea for avian species by analyzing the change in the number of species observed and population trends.

2.0 Data

Two separate Christmas Bird Count data of north and south shores of the Salton Sea are analyzed. The survey period includes annual counts from 1969 to 1998, except for 1969, '84, '85, and '87 of the North Shore. Each record consists of common name, scientific name, year, number observed, number of observers, and observation hours.

3.0 Tools

Microsoft Access and Microsoft Excel were used for the analysis.

4.0 Analytical Approach

4.1 Group Population

For each census year, there are more than 100 species of birds reported. Because the Salton Sea has a variety of habitats, the species with similar feeding habitats are grouped together [*]. Different feeding guilds include agricultural fields, fish-eating birds, shorebirds, waders, and waterfowl.

There are several species that are threatened or rely heavily on the Salton Sea. The trends of these key species are analyzed individually. These species include Double-crested Cormorant, American White Pelican, Brown Pelican, Eared Grebe, and Geese species.

Many of the species observed at the Salton Sea are migratory. Numbers of these species are affected by a variety of factors not directly related to the Salton Sea, such as availability of food at other places, the condition of their breeding grounds, climate, and normal variance in migratory numbers. All the species that make the Salton Sea their permanent home are considered resident and are grouped together.

4.2 Trend Analysis

The number of birds observed are affected by several factors including the number of observers and the total hours they spent observing (observation hours). One attempt to normalize this is to divide the population by the number of observers and/or the total observation hours. There are other factors affecting the population that would require further data collection and analysis. For this report, the normalizing technique is applied only to the South Shore population, the North Shore population, and the total population of the Salton Sea for comparison, but not to individual feeding guilds.

The results of the analysis indicate trends of increasing or decreasing numbers, or are inconclusive. An inconclusive result with relatively prominent trend can be considered to have a positive or negative trend. Regression analysis is used to determine the trends. Regression analysis gives three important values: R-square, P value and x-coefficient. The R-square represents how well the regression line fits to the actual data. R-square values of greater than 50 % indicate a positive fit of actual data to the linear regression line. The P value shows the probability that the data is random assuming its variance. P values of less than 5% are considered to represent definite trends. A positive or negative x-coefficient indicates an increase or decrease in bird populations.

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[*] Some species are counted more than once since they have more than one kind of habitat. For example, geese species are counted for both agricultural fields and waterfowl. Also, many species, such as passerines, are excluded from the analysis because their numbers do not represent Salton Sea related habitats.

4.3 Biodiversity

Biodiversity is a measure of how well the total bird population is distributed among different species. Biodiversity may be represented by the following equation:

> Biodiversity index = -Sum (pi*log2 pi), where pi represents the relative population of each species
> Max Biodiversity = N*(-Sum (1/N*log2 1/N), where N = number of possible observed species
> Biodiversity value = Biodiversity index / Max Biodiversity

The biodiversity index is calculated for each count year. It is then divided by the max biodiversity value to obtain biodiversity value. The highest possible biodiversity value is 1. High biodiversity indices mean that the total population of birds is evenly distributed amongst all possible observed species.

4.4 Number of Species

Change in the number of species recorded may be a good measure of the change in avian ecology of the Salton Sea. The surveys at the North Shore and the South Shore are analyzed individually. Total numbers of species are not calculated.

Changes in the numbers of species are observed in three different categories: Total number of species, Common species, and Vagrant species. Common species are defined as the species with greater than certain numbers of individual counted each year (100, 300, or 500). Vagrant species are defined as the species with less than certain numbers of individual counted each year (10, 2, or 1).

Note that there are other ways of defining common and vagrant species using population trend for each species. See the discussion.

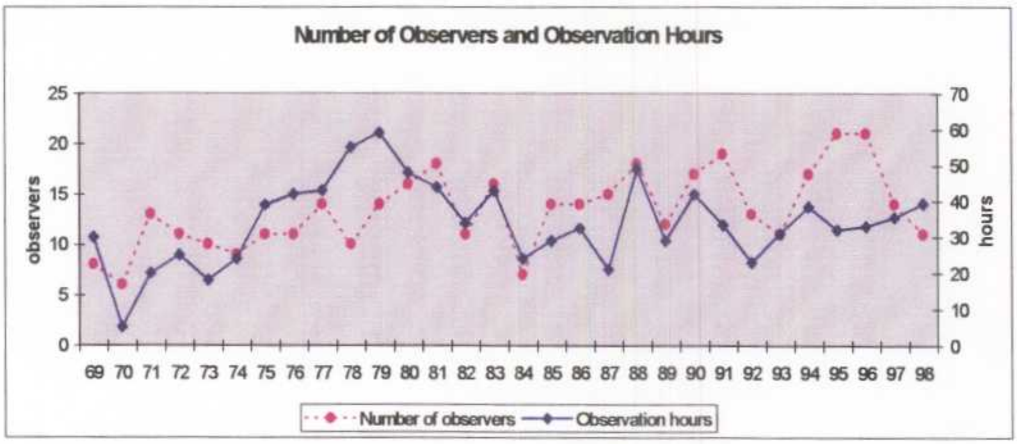
5.0 Results

5.1 Observation Data

An analysis of the observation hours and number of observers is performed by using the regression analysis tool in Excel. Trend is determined if R-square is more than 50 % and P value is less than 5 %. The coefficient represents the magnitude and the sign of trend.

Regression Analysis	R-Square	P value	Coefficient	Trend
Observation Hours	0.032889	0.337514	0.238865	inconclusive
Number of observers	0.331812	0.000865	0.254060	inconclusive

The result of this regression analysis is inconclusive because of low R-square values, but the number of observers has a more positive trend than observation hours, as shown by a much higher R-square value at 33% and very low P value of less than 0.1%.

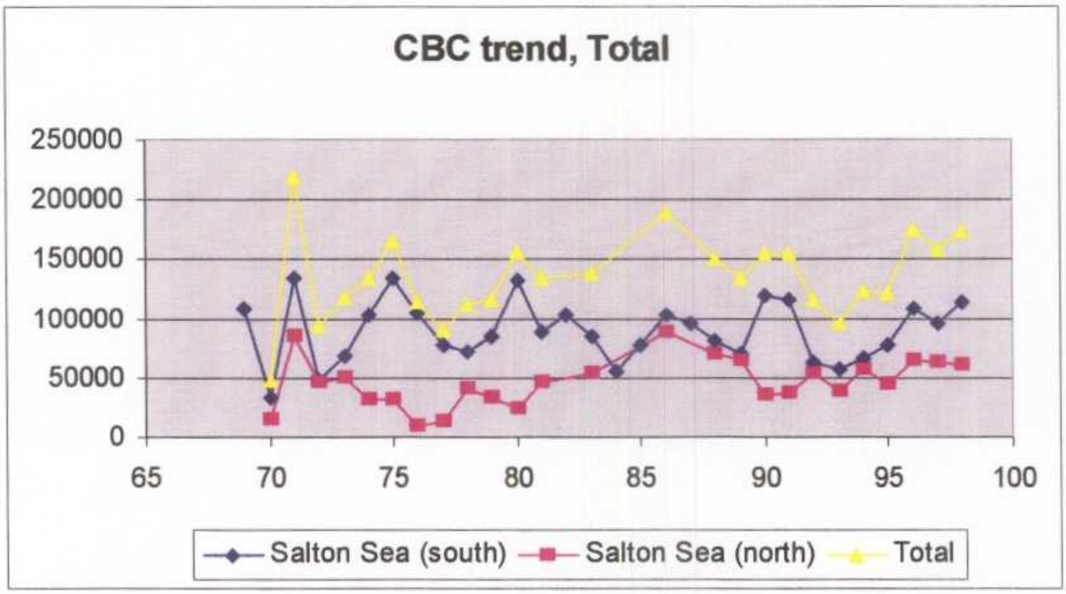


5.2 Population Trend Analysis

Population trends of different groups of species are analyzed.

Regression Analysis	R-Square	P value	Coefficient	Trend
South Shore	0.000143	0.949906	35.500334	Inconclusive
North Shore	0.149502	0.056221	861.184935	Inconclusive
Salton Sea Total	0.071975	0.194749	1054.001706	Inconclusive

Definite linear trends cannot be seen for South Shore total, North Shore total, and Salton Sea total. Overall, the population trend is slightly positive. North Shore population has a more positive trend than the South Shore population, as indicated by a higher Coefficient and a lower *P* value.



5.3 Feeding Guild Analysis

The feeding guild analysis is only performed on the South Shore populations. Note that the North Shore populations and the Salton Sea total populations may have significantly different trends from the South Shore.

Species	R-square	P value	Coefficient	Trend
Resident	0.000096	0.958940	-18.641824	Inconclusive
Ag field	0.000164	0.946452	7.307453	Inconclusive
Fish	0.389865	0.000226	231.266296	Inconclusive
Waterfowl	0.039051	0.295215	-398.459177	Inconclusive
Shorebird	0.285246	0.002366	188.003782	Inconclusive
Wader	0.044525	0.263011	18.866741	Inconclusive

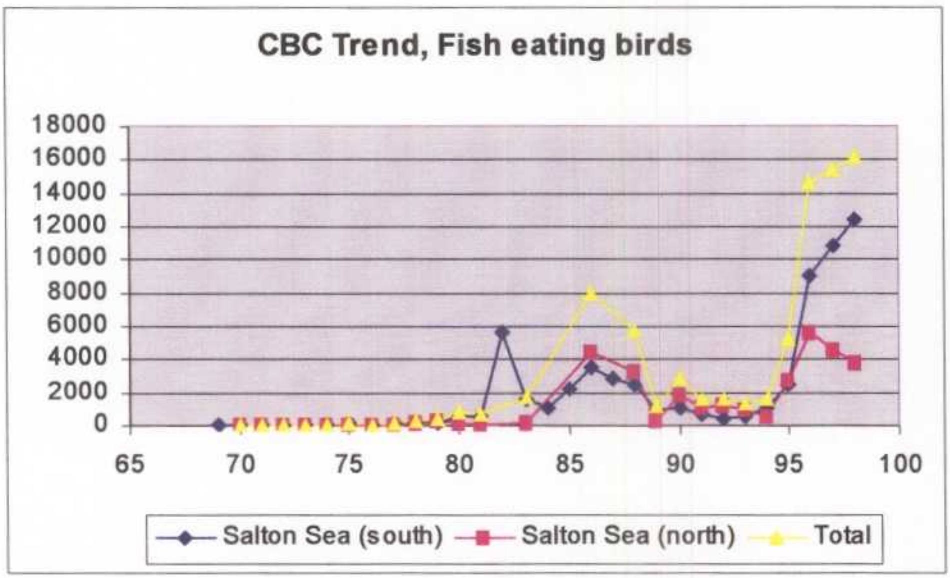
The result of the regression analysis is inconclusive because of low *R*-square values. Of the six groups of bird species, Fish eating birds and Shorebirds show positive trends, only ones with relatively high R-square values, 39% and 29% respectively. Other four have very small R-square value, meaning linear trends do not fit well.

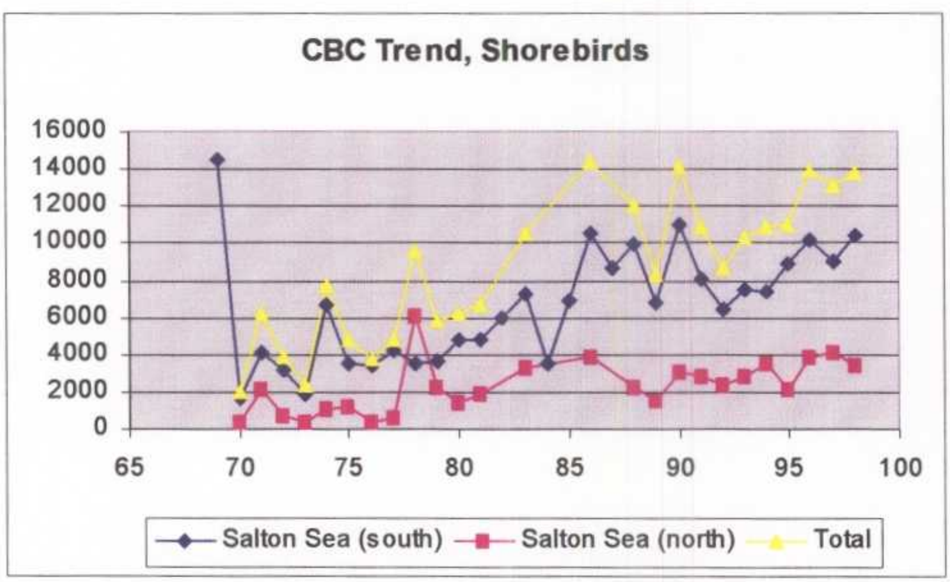
Fish eating birds

The regression analysis indicates a positive trend. Significant increase in recent years after a period of small populations in the early 90s can be seen from the graph. The South Shore population has increased more than the North Shore in the late 90s.

Shorebirds

The regression analysis indicates a positive trend with high variance. North shore has a relatively steady population.



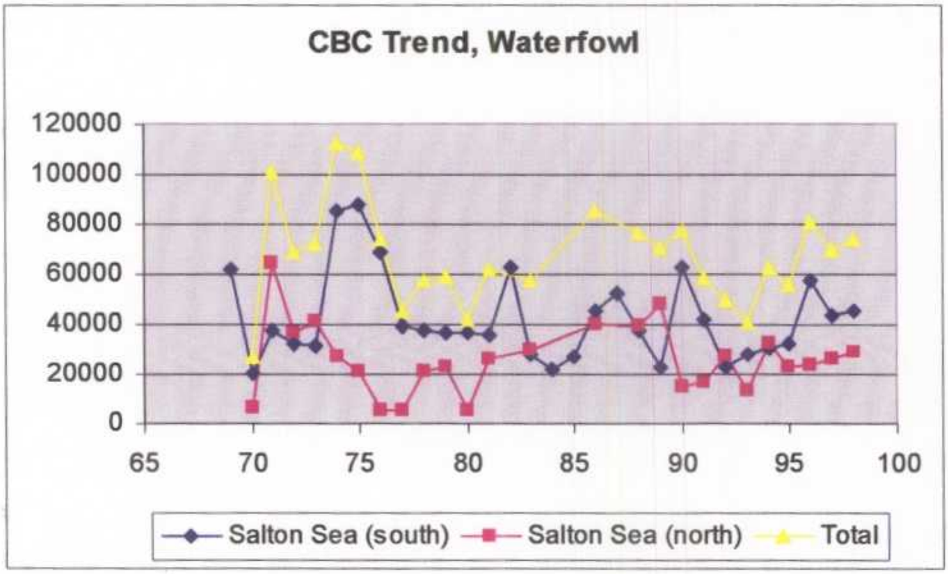


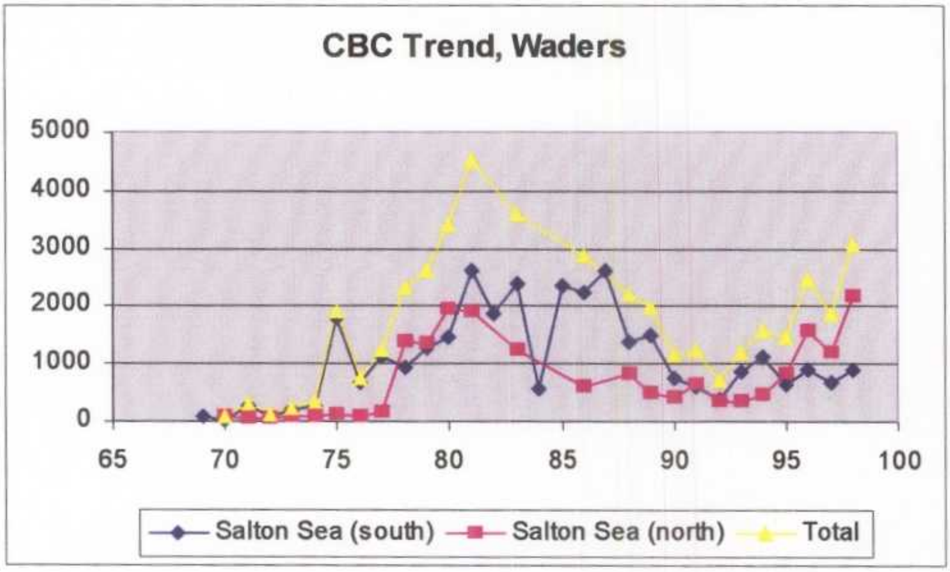
Waterfowl

The regression analysis is inconclusive, but indicates a negative trend, as shown by a negative and relatively large coefficient value of –398. There is no apparent correlation between the South Shore and the North Shore populations.

Waders

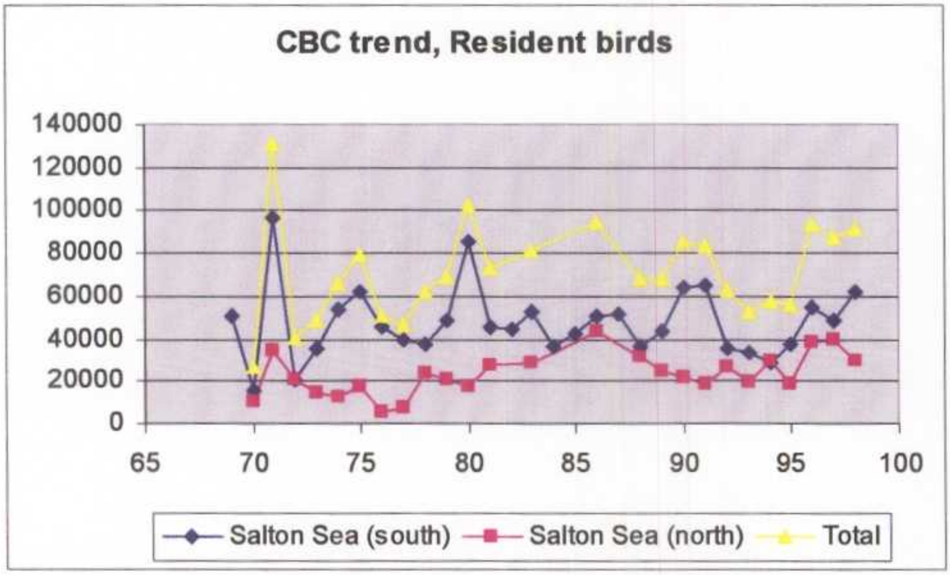
The regression analysis is inconclusive. The graph indicates the highest population in the early 80s. The South Shore population is significantly lower in 1984 than the other years in the same period.

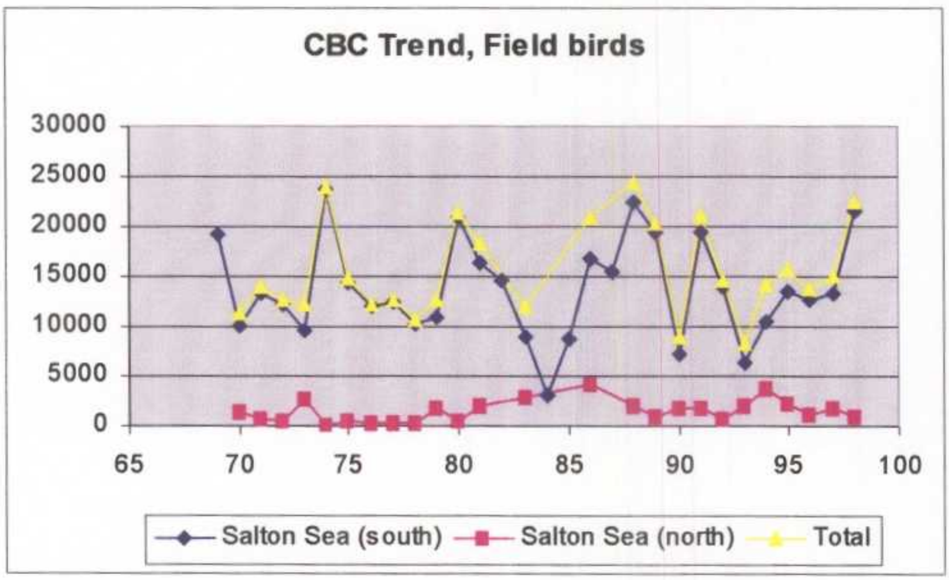




Resident birds
The regression analysis is inconclusive. The graph indicates a slight negative trend in the South Shore population and a slight positive trend in the North Shore population.

Field birds
The regression analysis is inconclusive. The graph indicates that the South Shore population is much higher than the North Shore population. The South Shore population has a drop in 1984 similar to Shorebirds and Waders.





5.4 Individual species

The regression analysis is performed on the key individual species. The Geese group consists of several species, including Canada Goose, Snow Goose, and Ross' Goose.

Species	R-square	P value	Coefficient	Trend
Geese	0.185465	0.017516	-225.955061	Inconclusive
White Pelican	0.205076	0.011974	70.754171	Inconclusive
Cormorant	0.455274	0.000043	141.210456	Inconclusive
Brown Pelican	0.257508	0.004205	13.498999	Inconclusive

The regression analysis in inconclusive because of low *R*-square values. All species have some indication of trend, as shown by low *P* values.

Geese

The regression analysis indicates a negative trend in the South Shore population, as shown by a negative *P* value. The North Shore population is much smaller than the South Shore population. The graph indicates a negative trend for the North Shore population as well. Note that the North Shore population is plotted against the secondary Y-axis.

Double-crested Cormorant

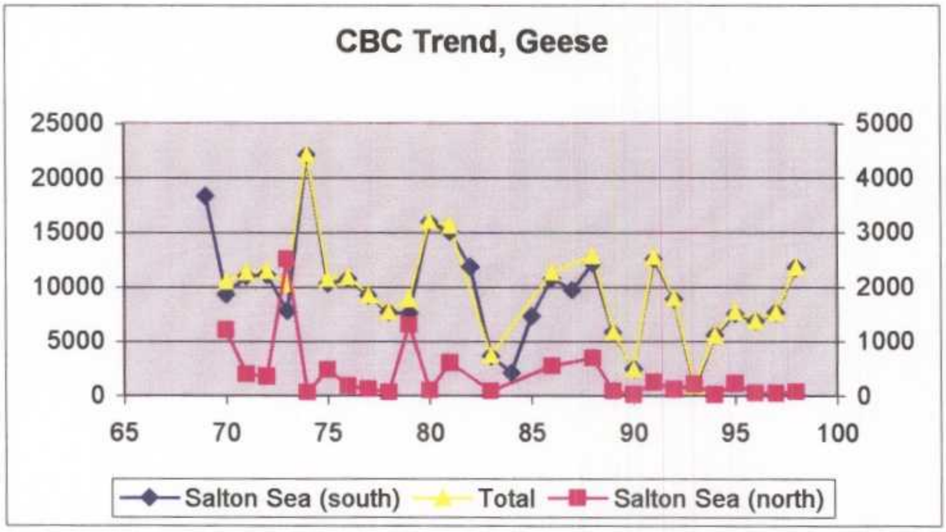
The graph indicates a significant increase in the late 90s for both the South Shore and the North Shore populations. There is a period of low population in the early 90s.

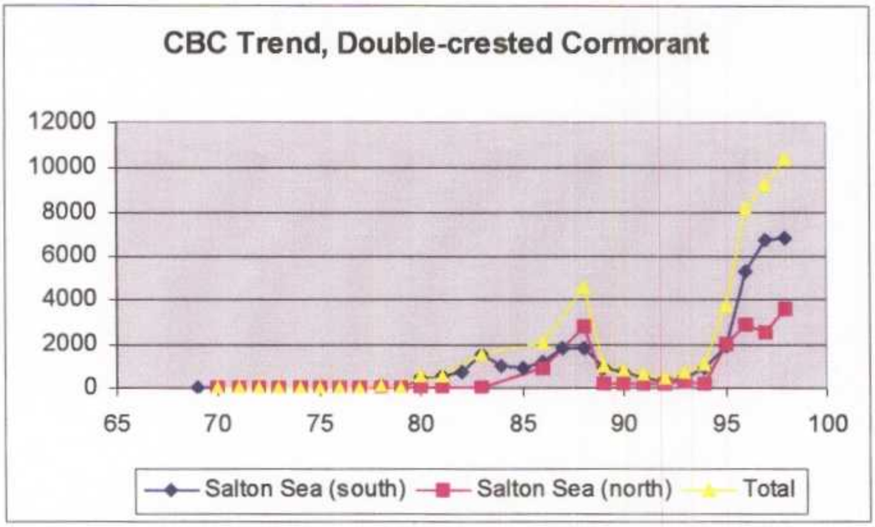
American White Pelican

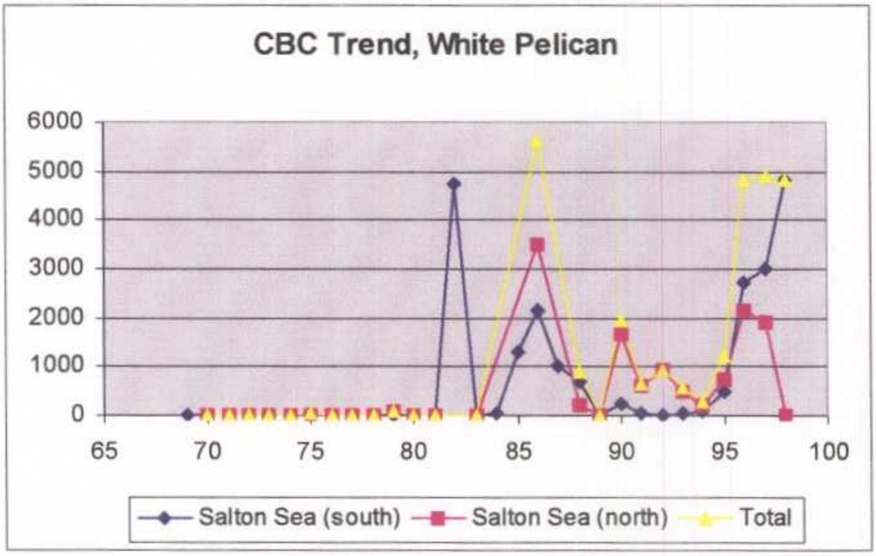
The graph indicates that the population is highly variable since the early 80s. The South Shore and North Shore populations have similar trends, except for 1998. The graph may indicate that the North Shore population moved to the south in 1998.

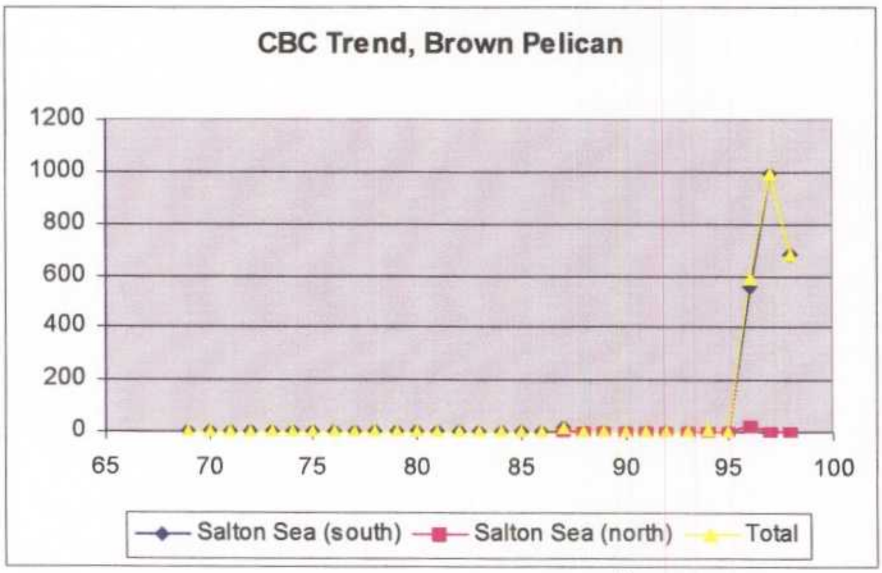
Brown Pelican

There has been very few individuals observed until very recently. The North Shore population is still very low.




CBC Trend, Double-crested Cormorant
12000
10000
8000
6000
4000
2000
0
65
70
75
80
85
90
95
100
Salton Sea (south)
Salton Sea (north)
Total


CBC Trend, White Pelican
6000
5000
4000
3000
2000
1000
0
65
70
75
80
85
90
95
100
Salton Sea (south)
Salton Sea (north)
Total

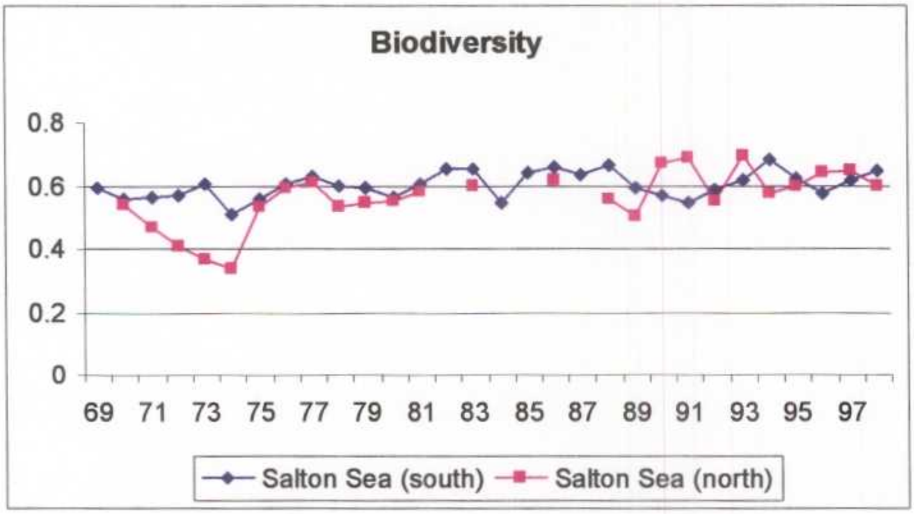

CBC Trend, Brown Pelican
1200
1000
800
600
400
200
0
65
70
75
80
85
90
95
100
Salton Sea (south)
Salton Sea (north)
Total

5.5 Biodiversity Analysis

The regression analysis is performed on the biodiversity values.

Biodiversity	R-square	P value	Coefficient	Trend
South	0.163797	0.026525	0.001921	Inconclusive
North	0.438438	0.000311	0.006580	Inconclusive

Trend analysis is inconclusive because of low *R*-square values. Small *P* values and positive coefficients indicate positive trends, especially for the North Shore.



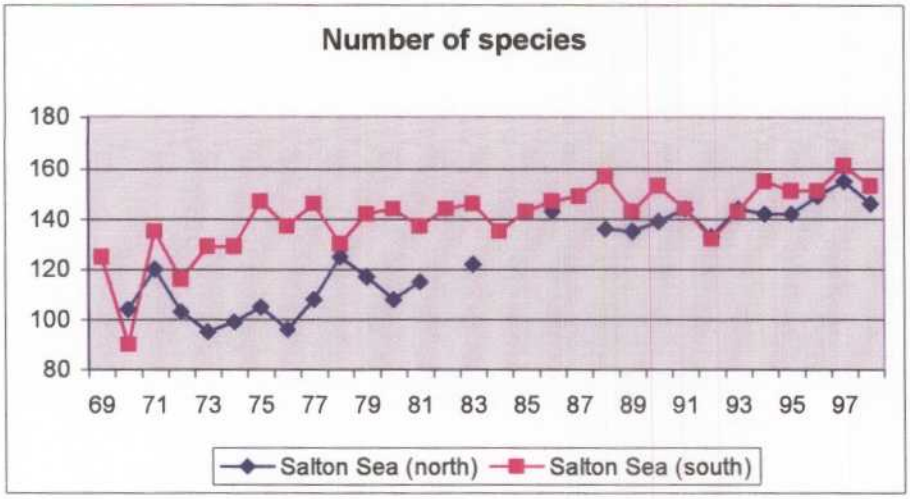
5.6 Number of Species

The total number of species is one value that is unlikely to be affected by the variance in the number of observers and the observation hours. The number of species observed has a strong increasing trend. It grew from about 130 species in early 70s to more than 150 species. Excluding 90 species in 1970 when the survey was much shorter than usual, the low is 116 species in 1972 and the high is 161 species in 1997. The regression analysis is performed on the number of species.

Total

Regression Analysis	R-Square	P value	Coefficient	Trend
North shore total	0.837025	0.000000	1.883086	increasing
South shore total	0.500767	0.000012	1.120356	increasing

The regression analysis shows very strong indication of increase in the number of species for both the South Shore and North Shore total. The average number of species increasing is more than one species each year The number of observation hours, however, does not have a definite increasing trend as shown by high *P* value and very small *R*-square value in the previous analysis.

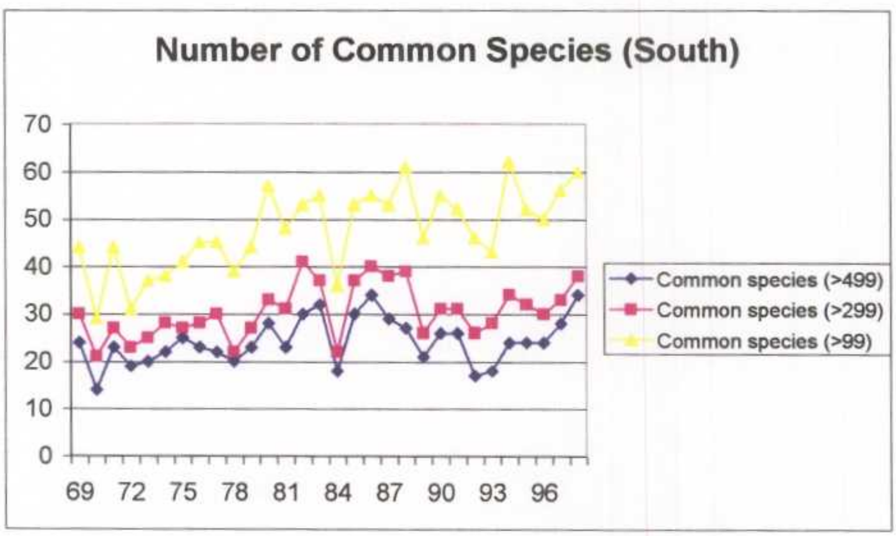


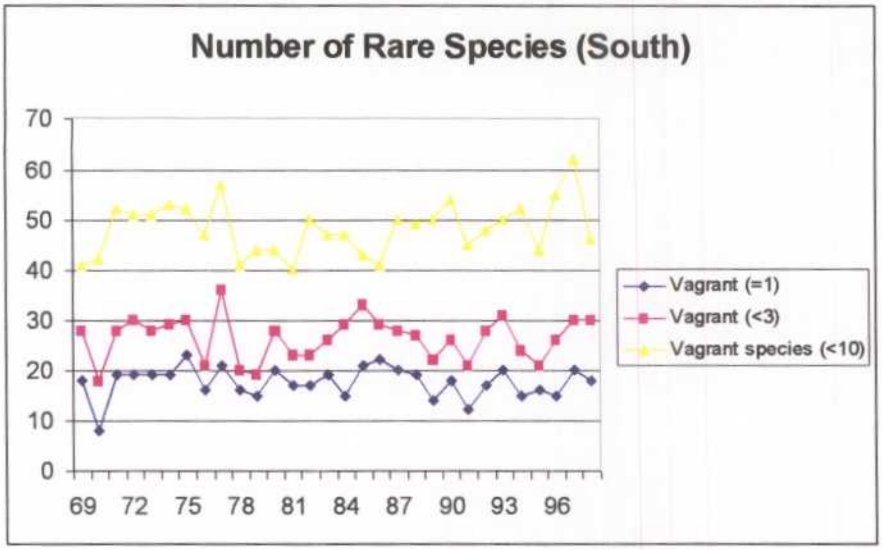
5.7 Common and Rare Species

The analysis of the numbers of common and rare species is performed only for the South Shore.

Regression Analysis	R-Square	P value	Coefficient	Trend
Common (>99)	0.460109	0.000038	0.663849	inconclusive
Common (>299)	0.196897	0.014041	0.283204	inconclusive
Common (>499)	0.119487	0.061345	0.193993	inconclusive
Vagrant (<10)	0.049153	0.239016	0.132592	inconclusive
Vagrant (<3)	0.001054	0.864780	0.016018	inconclusive
Vagrant (=1)	0.001632	0.832150	-0.014238	inconclusive

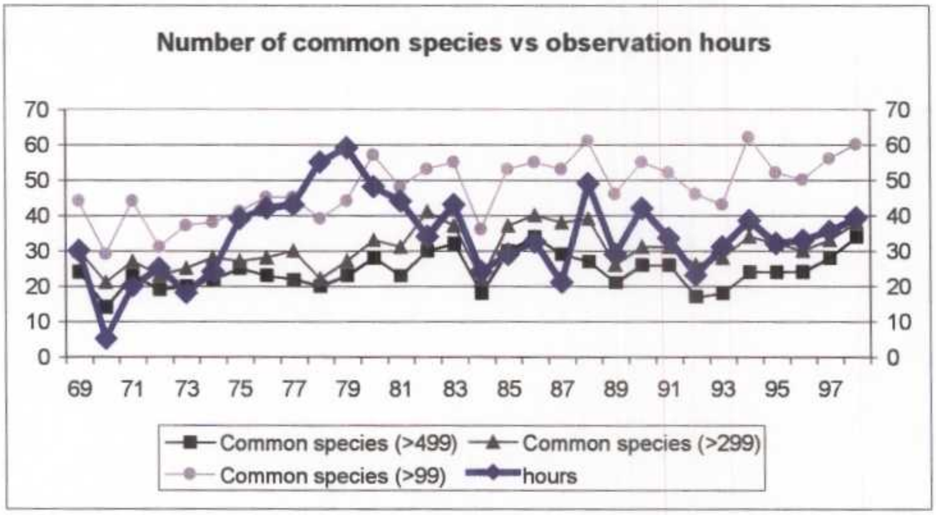
The regression analysis is inconclusive. Common species (>99) has the most positive trend shown by a high R-square value close to 50% and a very low P value. Vagrant species groups in general have more random trend than the Common species, as indicated by very low R-square values and high P value.



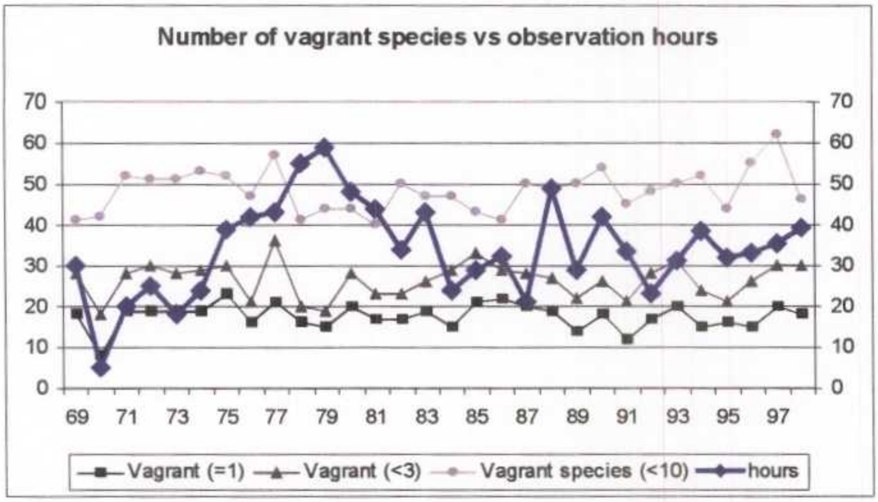


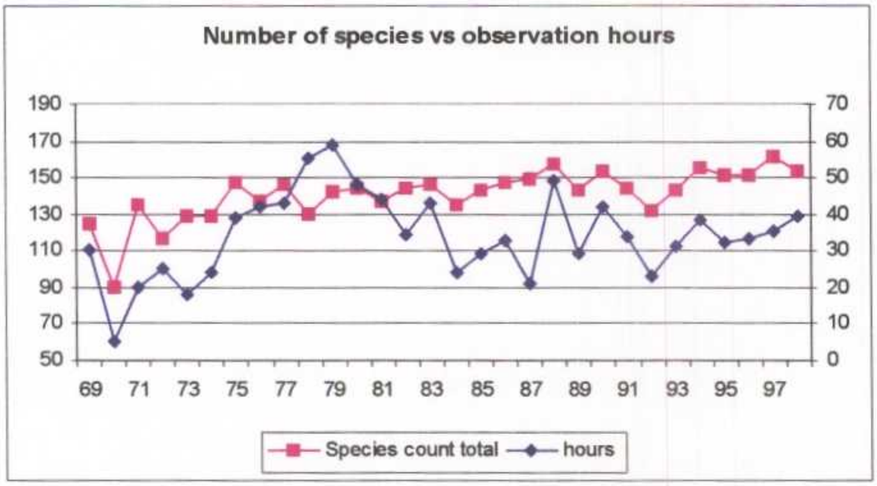
5.8 Number of Species and Observation Hours

Strong correlation between the number of common species and observation hours can be seen from the graph. This might be caused by how the Common species groups are defined. Common species is defined as the number of species whose count is higher than certain numbers (100, 300, and 500). With higher observation time available, the number of individual counts for each species increases, causing more species to go over the set count numbers which are used to separate common species from the others.



On the other hand, the number of vagrant species does not seem to be affected very much by observation hours. It could mean two things. One, higher observation time does not help the observers finding yet unseen species nor more number of relatively rare species, which is either in Vagrant (=1), (<3), or (<10). Two, higher observation time allows the observers to find more unseen birds and also rare species. Species in Vagrant (<3) category are moved up to the next level (<10) but new species are found as well so the number is not affected. In this case, the total number of species increases as well. The former is more likely since the total number of species seem to be less affected by the observation hours.

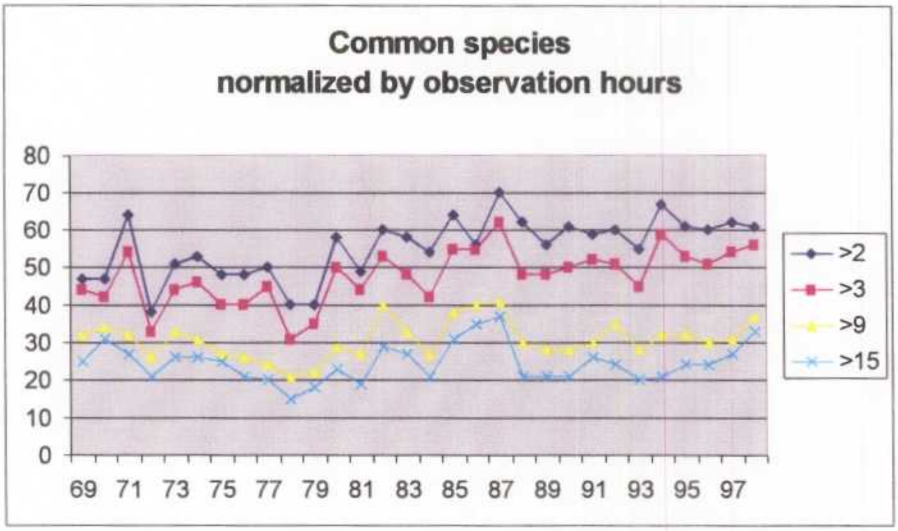




5.9 Normalized Common Species

One way to fix this problem is to divide the number observed for each species by observation hours and then separate the common species from the rest. Observation hours ranges from 5 to 59 with mean = 34 and standard deviation = 11. It is possible to obtain similar common species divider number by dividing the previous common species count of 99, 299, and 499 with the mean observation hours of 34. The new dividers are 2, 3, 9, and 15.

Regression Analysis	R-Square	P value	Coefficient	Trend
Common (>2)	0.405668	0.000154	0.584427	Inconclusive
Common (>3)	0.346694	0.000619	0.495662	Inconclusive
Common (>9)	0.055209	0.211350	0.135261	Inconclusive
Common (>15)	0.008490	0.628197	0.053615	Inconclusive



The regression analysis is inconclusive but indicates positive trend. One interesting pattern is that the positive trend gets stronger as the category becomes more inclusive. The number of very abundant species seems to have more random trend than the number of common species, which includes less abundant but still common species as well as very abundant species.

Following conjecture can be made from the result of the analysis.

Consider a spectrum of the relative abundance of species from very rare to very abundant. The number of species has a more positive trend toward the middle part of the spectrum than the edges.

5.10 Abundance Spectrum

The spectrum is divided into six categories: rare, uncommon, common, abundant, very abundant, and garbage birds. The border numbers are chosen so that each category consists of about from 10 to 20% of the total. Rare for the normalized version is 0.2 (30%) because it is the lowest value possible for year 1970, when there were only 5 observers. Otherwise, the border numbers for the normalized version are comparable to the original by looking at the values multiplied by the mean of observation hours.

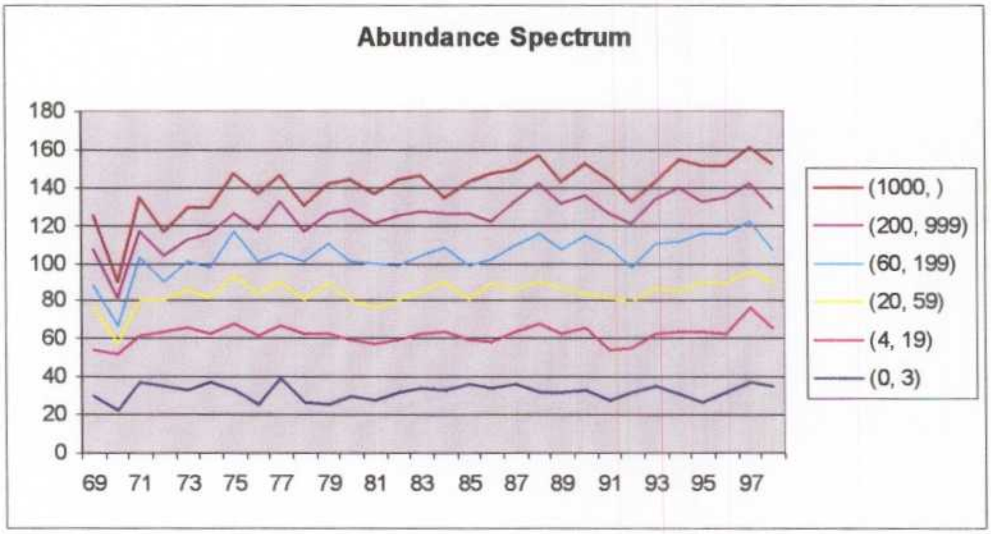
Normalized	Normalized * 34 (hours mean)	Original
0.2	6.8	3
0.7	23.8	20
2	68	60
6	204	200
35	1190	1000

Original data

Species count	R-Square	P value	Coefficient	Ratio
Rare (0, 3)	0.023446	0.419193	0.071858	0.23
Uncommon (4, 19)	0.034578	0.325197	0.097887	0.22
Common (20, 59)	0.177597	0.020376	0.216463	0.16
Abundant (60, 199)	0.398821	0.000182	0.380868	0.14
Very Abundant (200, 999)	0.242987	0.005646	0.278977	0.14
Garbage Birds (1000,)	0.027244	0.383400	0.074305	0.11

The regression analysis is inconclusive because of R-square values lower than 50%.

Very small R square values for Rare, Uncommon and Garbage birds indicate no linear trends. Abundant group has higher R-square though not quite 50 %, lower P value, and higher coefficient than either Common or Very abundant. R-square, p value, and coefficient all indicate that the positive trend is stronger in the middle and less towards the edges.

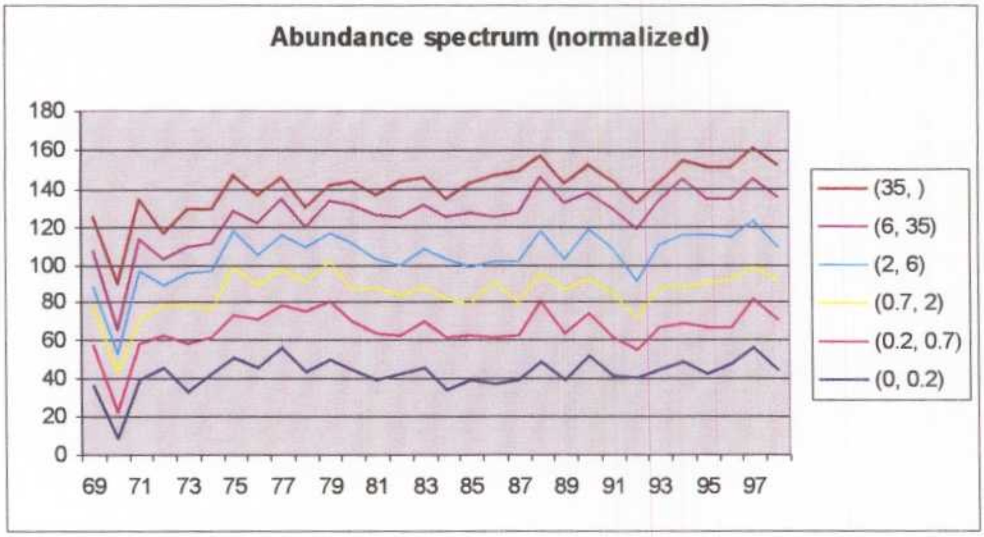


Normalized data by observation hours

Species count	R-Square	P value	Coefficient	Ratio
Rare (0, 0.2)	0.130397	0.049933	0.360623	0.30
Uncommon (0.2, 0.7)	0.027199	0.383803	0.080979	0.16
Common (0.7, 2)	0.045482	0.257826	0.093215	0.14
Abundant (2, 6)	0.290471	0.002119	0.298776	0.14
Very Abundant (6, 35)	0.454173	0.000045	0.416240	0.15
Garbage Birds (35,)	0.071923	0.151889	-0.129477	0.11

Trend analysis is inconclusive for all of them since all has R-square lower than 50%.

Very abundant has the most increase of all 12 groups with R-square almost 50% (45%). R square, p value, and coefficient all show that the increase is higher in the middle and less towards the edges with the exception of Rare (0, 0.2), which is expected since the number of rare species is not affected by the observation hours very much.



One interesting difference between the original and the normalized is that they have different group of the highest increase. It shows that the original has the highest increase at Common (60, 199) while the normalized has the highest increase at Abundant (6, 35), which is comparable to (204, 1190).

6.0 Discussion

6.1 Common Species

It is necessary to differentiate between commonly observed birds and abundant birds. A species with high population variance may be considered less common, although in some years its population can be very high. Similarly, a species with low variance may be considered common because its population level might be low but stable (consistently seen every year).

Another thing to consider is that some species are more difficult to see than others. Any time there is a direct comparison of the population of one species to the population of another, it is important to distinguish between observed population and the actual population of the species. For example, suppose that there are 10 rails and 1000 geese observed. The actual population of the rail might be 1000 because it is so hard to spot rails, whereas a count of 1000 geese is probably fairly close to its actual population because they are usually found in open fields.

Similar argument can be made for vagrant species as well.

6.2 About Normalizing

The number of birds observed is affected by the number of the observers and the observation hours. The more observers spending more time observing, the higher the total number of birds observed. It is important to know that trend analyses for both the numbers of observers and observation hours are inconclusive though generally they positive trends.

The actual population can be better estimated from the observed population by using observation hours and other survey variables as well as ease of observation among different species. (e.g. 1 for geese, 0.01 for rails)

6.3 Further Analyses

Migratory species population can be compared to the CBC data of other similar areas of similar latitude along the Pacific Coast Flyway. The relative population of the Salton Sea can be observed this way. (What is the ratio of the birds which prefer the Salton Sea to other wetlands habitat)

Population stability of each species can be observed by analyzing individual species trend. What does the stable population of a species (group) or an increase in population stability at the Salton Sea mean?

There are several population "spikes" observed for some species. For example, the South Shore population of American White Pelican in 1982 is close to 5000 and much higher than either the preceding or following years. The frequency and magnitude of spikes may indicate something about particular species (e.g. species with a spike every 10 years) or particular years (e.g. year with relatively high number of spikes).

7.0 Conclusion

The number of species at the Salton Sea is definitely increasing. In the past 30 years, the number of species increased by roughly 25 species and currently about 150 species are observed each year. The number of common species observed appears to be increasing more than the number of vagrant species. This may indicate increasing stability of the bird population at the Salton Sea.

There is no conclusive evidence that the total number of bird observed is increasing or decreasing in spite of the increase in the number of species.

The populations of fish-eating birds and shorebirds are increasing. Considering the migratory nature of these birds, this result indicates that the Salton Sea ecology is getting better, or other habitats on the Pacific Flyway is diminishing, causing more birds to use the Salton Sea.

Each key species have a definite trend. The population of Brown Pelican is considerably higher in the South Shore recently than any time in the past and in the North Shore. American White Pelican and Double-crested Cormorant have a similar trend. The first significant population appears in the 80s, and currently the populations of both species are increasing after a period of low population in the early 90s. The population of Geese is highly variable, but shows a decreasing trend.

The importance of the Salton Sea for the avian species is definitely increasing. More than 90% of the wetland habitats on Pacific Flyway is lost in the last 200 years. The geography and the size of the Salton Sea make it one of the few reliable stops for the migrating birds. Because more and more migratory birds are relying on the Salton Sea, ecological breakdown of the Salton Sea would have a huge impact on the birds of Pacific Flyway. The number of fish-eating birds has increased dramatically in the last 30 years while the water quality of the Salton Sea has become worse, causing diseases more often than before. While there seems to be no indication of the decline in the quality of the Salton Sea ecology from this analysis, high reliance of the avian species on the Salton Sea leave them vulnerable to the potential ecological letdown, making the stable ecology of the Salton Sea more important.

Resident
Abert's Towhee
American Avocet
American Coot
American Kestrel
American White Pelican
Anna's Hummingbird
Black Phoebe
Black-crowned Night-Heron
Black-necked Stilt
Black-tailed Gnatcatcher
Brown-headed Cowbird
Burrowing Owl
Cactus Wren
California Gull
Caspian Tern
Cattle Egret
Cinnamon Teal
Clapper Rail
Clark's Grebe
Common Ground-Dove
Common Moorhen
Common Raven
Common Yellowthroat
Crissal Thrasher
Double-crested Cormorant
European Starling
Forster's Tern
Gambel's Quail
Great Blue Heron
Great Egret
Great Horned Owl
Great-tailed Grackle
Greater Roadrunner
Green Heron
Green-backed Heron
House Finch
House Sparrow
Inca Dove
Killdeer
Ladder-backed Woodpecker
Least Bittern
Mallard
Marsh Wren
Mourning Dove
Northern Mockingbird
Osprey
Red-tailed Hawk
Red-winged Blackbird
Redhead
Ring-billed Gull
Rock Dove
Ruddy Duck
Savannah Sparrow
Snowy Egret
Song Sparrow
Turkey Vulture
Verdin
Virginia Rail
Western Grebe
Yellow-footed Gull

Waterfowl
(large forms) Canada Goose
blue morph Ross's Goose
Brant
Cackling Goose
Canada Goose
Canada Goose (small races)
Greater White-fronted Goose
Lesser Snow Goose
Ross's Goose
Snow Goose
Snow Goose (blue form)
Snow Goose (white form)
white goose sp.
White-fronted Goose
American Coot
American Goldeneye
American Green-winged Teal
American Wigeon
Baldpate
Barrow's Goldeneye
Black Scoter
Black Skimmer
Blue-winged Teal
Bufflehead
Canvasback
Cinnamon Teal
Common Goldeneye
Common Moorhen
Coot
duck sp.
Eared Grebe
Eurasian Wigeon
Florida Gallinule
Fulvous Whistling-Duck
Gadwall
Greater Scaup
Green-winged Teal
Horned Grebe
Lesser Scaup
Mallard
Northern Pintail
Northern Shoveler
Oldsquaw
Pied-billed Grebe
Pintail
Redhead
Ring-necked Duck
Ruddy Duck
Ruff
scaup sp.
Shoveler
Surf Scoter
Tundra Swan
Whistling Swan
White-winged Scoter
Wood Duck

Shorebirds
Hudsonian Curlew
Killdeer
Long-billed Curlew
Whimbrel
White Ibis
White-faced Ibis
American Avocet
Avocet
Black Turnstone
Black-bellied Plover
Black-necked Stilt
Common Snipe
Dowitcher sp.
Dunlin
Greater Yellowlegs
Least Sandpiper
Lesser Golden-Plover
Lesser Yellowlegs
Long-billed Dowitcher
Marbled Godwit
Pectoral Sandpiper
Peep sp.
Phalaropus sp.
Red-backed Sandpiper
Red-necked Phalarope
Ringed Plover
Ruddy Turnstone
Semipalmated Plover
Short-billed Dowitcher
Snowy Plover
Solitary Sandpiper
Spotted Sandpiper
Stilt Sandpiper
Western Sandpiper
Western Willet
Willet

Wilson's Phalarope
Wilson's Snipe
yellowlegs sp.

Waders
Black Rail
Clapper Rail
Sora
Virginia Rail
American Bittern
American Egret
Black-crowned Night-Heron
Brewster's Egret
Great Blue Heron (Blue form)
Great Egret
Green Heron
Green-backed Heron
Least Bittern
Little Blue Heron
Snowy Egret
Tricolored Heron

Fish
Double-crested Cormorant
Farallon Cormorant
Caspian Tern
Clark's Grebe
Clark's Grebe/Western Grebe
Common Loon
Common Merganser
Common Murre
Common Tern
Forster's Tern
Gull-billed Tern
Hooded Merganser
Pacific Loon
Red-breasted Merganser
Western (Western) Grebe
Western Grebe
American White Pelican
Brown Pelican
White Pelican
Osprey

Ag
Hudsonian Curlew
Killdeer
Long-billed Curlew
Whimbrel
White Ibis
White-faced Ibis
Abert's Towhee
Cattle Egret
Common Raven
Mountain Plover
Pheasant
Sandhill Crane
(large forms) Canada Goose
blue morph Ross's Goose
Brant
Cackling Goose
Canada Goose
Canada Goose (small races)
Greater White-fronted Goose
Lesser Snow Goose
Ross's Goose
Snow Goose
Snow Goose (blue form)
Snow Goose (white form)
white goose sp.
White-fronted Goose