



State of the Estuary Report 2015

Summary

PROCESSES – Feeding Chicks, Brandt's Cormorant

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State of the Estuary 2015: Processes

Brandt's Cormorant Reproductive Success Indicator

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1. Brief description of indicator and benchmark; background

The indicator is the number of fledged young produced per breeding pair at the breeding colony of Brandt's Cormorants (*Phalacrocorax penicillatus*) on Alcatraz Island, in San Francisco Bay. The indicator provides a measure of the health of the aquatic foodweb in the San Francisco Bay estuary. Brandt's Cormorants are entirely piscivorous and, thus, the reproductive success of breeding pairs reflects availability of food for the young in the open water of San Francisco Bay. The indicator has been studied on Alcatraz Island since 1995, as part of the monitoring conducted by the National Park Service. A comparable time series has been collected at the Brandt's Cormorant colony on the Farallon Islands by Point Blue Conservation Science since 1972.

The specific calculation used for assessment purposes is the mean reproductive success for the most recent 3 years. We compare that value to the reproductive success required to maintain a stable population, which is the benchmark criterion for Good. If the indicator value meets or exceeds the latter, the indicator is scored Good. The criterion for Poor was 60% that of Good, i.e., 40% reduction. If the indicator is at or below the scoring criterion for Poor the criterion is scored Poor.

2. Indicator status and trend measurements

Results for this indicator for 1995-2014 are displayed in Figure 1. The indicator was relatively stable between 1995 and 2007. In 2008, it exhibited a slight drop, followed by a strong decline in 2009. From 2009 to 2012, inclusive, the indicator was either scored Poor (2009, 2010, 2012) or Fair (2011). However, in the two most recent years (2013, 2014), the indicator has shown a sharp rebound. As a result, there is no significant ($P > 0.05$) linear trend. In addition, the mean value for the most recent three years is 1.67. This is above the benchmark value of 1.50 and is therefore scored as Good.

3. Brief write-up of scientific interpretation

What is this indicator?

The indicator is the number of fledged young produced per breeding pair at the breeding colony on Alcatraz Island, in San Francisco Bay. This colony has been studied since 1995 (Robinson et al. 2014) using standardized focal site surveys, comparable to studies conducted on the Farallon Islands (Boekelheide et al. 1990, Nur and Sydeman 1999a).

Why is it important?

There are two essential reasons for tracking and evaluating the reproductive success of the Brandt's Cormorant in San Francisco Bay. Above all, this metric provides a reliable index of prey availability for foraging seabirds in the bay, and thus provides an indicator of functioning of the aquatic foodweb in the bay. Brandt's Cormorant are piscivorous (Ainley and Boekelheide 1990), and, moreover, are apex marine predators. That the ability of parent birds to adequately feed their chicks is a good measure of prey availability has been well established through numerous studies, including long-term studies on the Farallon Islands nearby (Nur and Sydeman 1999a). Secondly, success at rearing chicks is a necessary requirement for healthy, self-sustaining populations (Nur and Sydeman 1999b).

What is the benchmark? How was it selected?

The benchmark for Good is the level of reproductive success that produces a stable population (given what is known regarding all other relevant demographic parameters). On the basis of calculations in Nur et al. (1994) (see also Nur & Sydeman 1999a, this value is 1.50 chicks fledged per breeding pair. The criterion for Poor is 60% that of Good. Thus, a reproductive success below 0.90 chicks per pair is the criterion for Poor. Reproductive success below 0.90 chicks for an extended period of time would have marked population consequences. We note that three of the recent years (2009, 2010, 2012) were below the Poor benchmark value.

Status and Trends

The most recent three-year mean is 1.67 young fledged per pair, which is scored Good. In fact, the most two recent years (2013, 2014) were 2.3 and 2.1 young fledged, respectively, which is in the top half of all results for the 20-year time series. In contrast, 2012 was an especially low value. Thus, after a four-year period of moderate to low reproductive success (2009-2012), Brandt's Cormorant success appears to have fully rebounded.

Over the period 1995-2008 there was no significant trend in the indicator. However, adding 2009-2012 to the time series resulted in a significant, linear declining trend. But with the addition of 2013 and 2014, there is currently no significant linear trend over the entire 20-year period, 1995-2014 ($P > 0.05$, for linear regression of chicks fledged in relation to year).

Significance/Interpretation

Starting in 2008, Brandt's Cormorants displayed a declining trend in reproductive success, which, in 2009, 2010, and 2012, reached extremely low levels. Similarly low reproductive success was observed on the Farallon Islands during these years, specifically 2008-2012, inclusive (Warzybok et al. 2014). Such low success indicated especially low prey availability in those years. In 2013 and 2014, however, reproductive success for Brandt's Cormorant on Alcatraz Island was very high, demonstrating a complete reversal of the earlier decline. Thus, a well-functioning foodweb, supporting forage fish and their predators, is indicated for the two most recent years. In general, principal prey species for Brandt's Cormorants are Northern

anchovy, rockfish (several species) and flatfish such as the Pacific sanddab (Nur and Sydeman 1999a). While anchovy have been rare or absent in recent years, in 2013 and 2014 rockfish and sand dabs have been well-represented (Point Blue unpublished).

Two consecutive years of high reproductive success is encouraging, but evaluation of reproductive success in 2015 will be required to confirm whether the situation continues to be favorable.

4. Related Figures.

Indicator results are displayed in Figure 1.

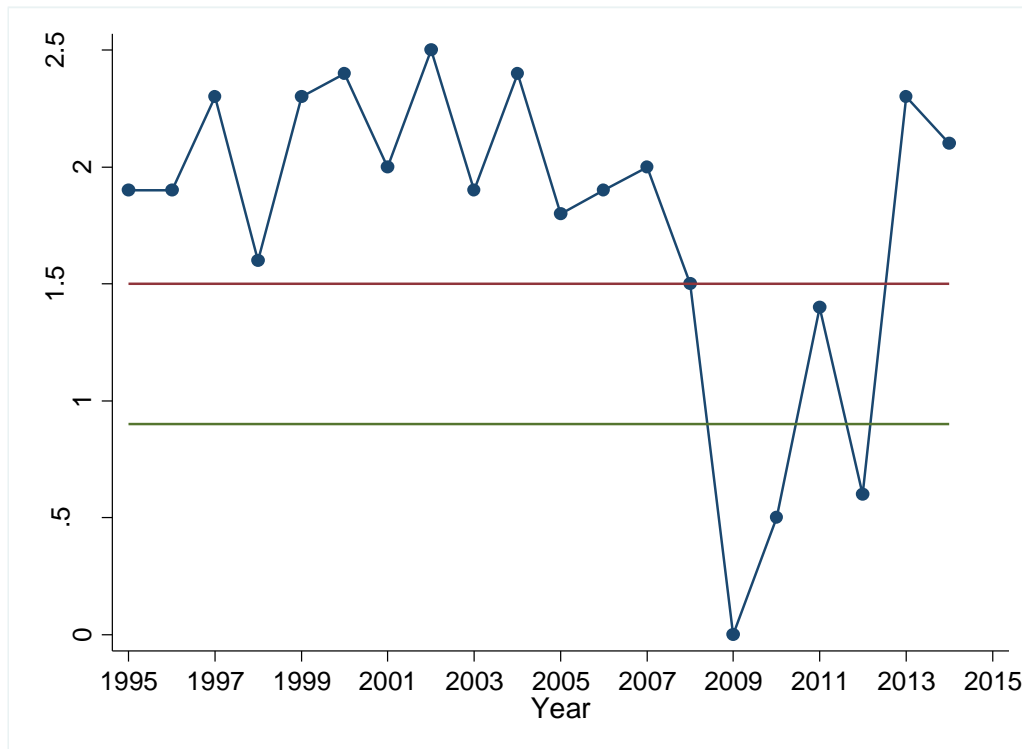


Figure 1. Brandt's Cormorant Reproductive Success Indicator. Mean reproductive success is shown for each year. The Benchmark Value for Good is 1.50 fledged young per pair (see text). The scoring criterion for Poor is 60% of the benchmark, i.e., 0.90 fledged young per pair.



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Technical Appendix

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5. Technical Appendix.

Background and Rationale

The reproductive success of seabirds and other waterbirds is a well-established indicator of ecosystem health. In particular, reproductive success of seabirds has been shown to be a good indicator of food availability for vertebrate predators (Parsons et al. 2008). Use of this indicator for Brandt's Cormorants on Alcatraz Island, work which was initiated in 1995, provides an especially informative indicator because we also have a long time series for the same species on the nearby Farallon Islands (Boekelheide et al. 1990, Nur and Sydeman 1999a, Warzybok et al. 2014). The same methods have been used in both colonies, facilitating comparison among the two time series.

From 1995 until 2007, reproductive success on Alcatraz Island remained high and relatively stable from year to year. In 2008, the lowest value as of then was observed: 1.50 chicks reared per pair. However in 2009 no chicks at all were reared in the colony (Robinson et al. 2014). In 2010 and 2012 reproductive success was very low (less than 0.75 chicks reared per pair) and even in 2011, reproductive success was lower than in any year observed between 1995 and 2008. However, in 2013 and 2014 reproductive success returned to the levels observed in 1995-2007.

Benchmark

Choice of benchmark: As noted above, the number of chicks reared to fledging is a well-established indicator of food availability for marine predators. At the same time, reproductive success is a key and necessary parameter to maintain healthy wildlife populations (Nur and Sydeman 1999b). Due to previous, intensive studies of Brandt's Cormorants on the nearby Farallon Islands (Boekelheide et al. 1990 and Nur and Sydeman 1999a), we are able to estimate the reproductive success per pair needed to produce a stable population, given our knowledge regarding survival rates of juveniles and adults and age of first breeding (Nur et al. 1994). That value, 1.50 chicks reared per pair, provides the benchmark value used here. Furthermore, we use the average value for the three most recent years for comparison. Use of a single year's value would not be as informative due to year to year variation in this indicator.

Data sources and Methods

The data collected and calculations made for this indicator were carried out by several investigators working on Alcatraz Island under the auspices of the National Park Service, most recently Robinson et al. (2014). That reference provides information on data collection and calculation of annual reproductive success. The time series on Brandt's Cormorant reproductive success on Alcatraz Island was initiated in 1995 and has continued through the present. Reproductive success is estimated at multiple sub-colonies on the island; in 2014, data were gathered from six sub-colonies. Sample size in each year has usually exceeded 150 pairs for the island. In 2014 the sample size was 167 breeding pairs. In a few years in the time series sample size was less than 100 (Robinson et al. 2014).

For analysis of the indicator we calculated the mean reproductive success over the past 3 years (i.e., during the current period) and compared that to the benchmark value (see above). We did

not calculate a standard error around the three-year average using the original field data since we did not have access to those data, but only the summary statistics. However, we do note that the three-year average is based on a sample of 541 breeding pair-years, and so confidence in that average is high.

Uncertainties and assumptions: Reproductive success among breeding pairs is well estimated on Alcatraz Island: a large sample of breeding pairs are monitored, spanning six or more sub-colonies in each year. However, not all mature Brandt's Cormorant attempt to breed in each year. Thus, poor food availability can lead to skipping of breeding (Nur and Sydeman 1999a) and this phenomenon cannot be captured with the current metric.

The choice of benchmark value depends on assumptions regarding survival and age of first breeding. The conclusion that two out of the last three years exceeded the benchmark value is a robust one and does not depend on the exact benchmark value used, since in 2013 and 2014 annual reproductive success was 2.1 or greater, substantially greater than the calculated benchmark value of 1.5. The greater uncertainty concerns the reproductive success achieved in 2015 and in future years. Will the favorable conditions observed in 2013 and 2014, similar to observations from 1995 to 2007, continue?

Peer Review and Acknowledgments

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