

**TECHNICAL REPORT
TO THE
CALIFORNIA COASTAL COMMISSION**

N. Integration of local depressions and increases
in fish stocks with inplant losses

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1.0 INTRODUCTION

Here we further integrate and explain observed changes in local fish populations near SONGS that were reported elsewhere (Interim Technical Report 3). We detected significant declines in the density of both queenfish and white croaker in the midwater near SONGS, as sampled by lampara seines. We also detected significant local increases in the density of both species near the bottom in the vicinity of SONGS as sampled by otter trawls. We address two important questions in this document: (1) Can the rate at which queenfish and white croaker are taken into SONGS and killed explain the observed local depressions in their density in the midwater region? (2) When the observed decreases in local density in the midwater are combined with the observed increases in local density on the bottom what is the overall change in the local standing stock?

Our approach to the first question was to use a simple model to determine whether the estimated rate at which fish are taken into the plant and killed could reasonably explain our estimated decreases in the local standing stocks. In order to apply this model two preliminary steps were done: (1) We converted the estimated local reductions in the midwater from "fish per set" of the lampara seine to a number of fish lost from the local population. (2) We also needed to estimate the rate at which fish were killed by being taken into SONGS.

In principle the second question can be answered simply by adding the losses in the midwater to the gains on the bottom. However, this is complicated by two facts. First lampara seines (midwater) and otter trawls (bottom) were taken at somewhat different depths and locations. This complicates our estimate of changes

in standing stock since we need to make assumptions about how large an area over which the observed changes in density have occurred. Second, the sizes (and hence ages) of fish caught by the two methods were different. Not only does this indicate that the observed changes are not simply due to movement of fish from the midwater to the bottom, but it also requires that we convert the losses in the midwater and gains on the bottom to changes in numbers of fish of a common age. This is required because fewer fish will survive to later ages naturally, so a given loss of fish is in effect a larger one if the lost fish are older.

2.0 BACKGROUND ON SAMPLING AND ASSUMED AREAS IMPACTED

Relative declines were detected for lampara catches of queenfish and white croaker (Interim Technical Report 3). Lampara seines were taken at the 5 m - 10 m and 11 m - 16 m depth contours. Lampara seines sampled the entire water column, from surface to bottom. At each depth contour, two Impact sites (at 0.5 km and 2.5 km south of SONGS) and one Control site (at 12 km south of SONGS) were sampled. A single lampara set sampled the entire water column under approximately 4,600 m² (0.0046 km²) of the ocean's surface area.

Relative increases in density (numbers caught per set) were detected in otter trawl catches of queenfish and white croaker (Interim Technical Report 3). Otter trawls were done at the 18 m and 30 m depth contours. Otter trawls sampled only bottom-oriented fish. Each trawl sampled approximately 950 m² (0.00095 km²) of bottom area.

The areas sampled by lampara and otter trawl did not overlap since lampara seines were taken inshore of otter trawls.

We make the following assumptions regarding the areas over which the observed changes detected by lampara seines and otter trawls occurred. (1) The losses detected by lampara seines occurred only within the areas that were sampled from the 5 m to the 16 m depth, an inshore - offshore distance extending 2 km. For white croaker we assume that the losses are restricted to the 5 m to 10 m depth range based on sampling data (see below). Our assumption that losses do not extend offshore (or inshore) of the sampling area is based on the most likely

mechanism for the losses, mortality of fish taken into the plant at the intake in 8 m of water (see DeMartini *et al.* 1987). (2) For queenfish we assume the impact extended over a four km longshore distance. We observed declines 2 km apart and downcoast from the intakes, and we assume an equal area upcoast of these stations was impacted. Thus, the estimated reductions in density are assumed to have occurred equally over a total of 8 km² (2 km inshore-offshore x 4 km longshore), and we assume that the local losses did not extend outside of this area. (3) For white croaker we assume losses extended 2 km in the longshore direction, and one km in the offshore direction. This smaller impact area was assumed because a decline was detected only at the near-shallow sampling station. Thus the estimated decline in the density of white croaker is assumed to have occurred over a 2 km² area, with no local losses extending beyond this area. (4) The increases detected on the bottom by otter trawls are assumed to have occurred only in the offshore area sampled by this method, extending a two km inshore - offshore distance, from the 18 m to the 30 m depth contour, and extending 1 km up and downcoast. These increases are assumed not to extend up into the water column, although the water column was not sampled by lampara seine over the 18 m - 30 m depth contours. Altogether we assume that the observed increases in the density of queenfish and white croaker extended over a 4 km² area of the bottom and no local increases extended outside of this area. Our assumption that increases apply only to the offshore area is based on the fact that the likely mechanism for the increase is an increase in food for these fish, benthic invertebrates (see DeMartini *et al.* 1987), and the increases in the density of these invertebrates were to the most part restricted to the offshore area, and were largest within a kilometer of the diffusers (Final Technical Report I).

We do not have the data needed to test our assumptions regarding the spatial extent of the impacts. Consequently our estimates of changes in local standing stocks should be considered quite rough ones. The assumption that decreases detected inshore and increases detected offshore and on the bottom are restricted to these areas are reasonable (a) because of the likely mechanisms for the effects and (b) for the inshore losses the entire water column was sampled so an increase in fish density near the bottom should have contributed to the results and offset losses in the water column. With regard to the upcoast - downcoast effects it seems likely that effects extended beyond the furthest sampling station at which effects were detected, but we can not be certain how far, especially when there were no other impact stations farther from the plant. These and other limitations to our analyses are discussed further in the Summary and Discussion section.

3.0 COMPUTATIONAL METHODS

3.1 A Simple Model Used to Evaluate Whether Inplant Losses Can Explain Local Depressions.

We use the following simple model to help judge whether the rate of inplant losses can explain the estimated depressions in midwater standing stocks.

Let

r = the natural population growth rate,

c = per capita rate of leaving the SONGS area,

I = the immigration rate to the SONGS area from outside,

s = the per capita death rate in the SONGS area due to intake loss,

N_p = the population size in the SONGS area, if unaffected by SONGS,

N_o = the population size in the SONGS area, once affected by SONGS.

$$N_p' = rN_p - cN_p + I \quad (' \text{ means derivative with respect to time})$$

$$N_o' = rN_o - cN_o + I - sN_o$$

At equilibrium:

$$N_p = I / (c - r),$$

$$N_o = I / (c - r + s).$$

$$N_o/N_p = (c - r) / (c - r - s).$$

There is no reason to think that r was any different in the SONGS area than elsewhere. Further we let $r = 0$, assuming the population in the larger area was at equilibrium.

$$\text{Now, } N_o/N_p = c / (c + s) \text{ and}$$

$$c = sN_o/(N_p - N_o) \text{ or}$$

$$c = s/(N_p/N_o - 1)$$

We can solve for c since we can estimate N_p , N_o , and sN_o (the daily intake loss). For example let N_p (the Expected abundance in the absence of SONGS) = 1,000,000; N_o (the Observed abundance) = 500,000; sN_o (the daily inplant loss) = 1000. $c = 0.002$, which equals the probability of a randomly chosen fish leaving the impact area on a given day. Assuming the probability of leaving on any given day is the same, then the average number of days before leaving is $1/c$ which equals 500 days. The mean residence time ($1/c$) provides a measure of the rate at which fish would need to leave the impact area in order for the estimated depression to obtain, given the estimated inplant loss rate. The higher the mean residence time, the less likely that inplant loss can explain the depression. Taking 500 days to leave the 8 km² impact area seems a bit high since pelagic fish on the open coast are generally believed to move distances of over 100 kilometers or more in a year. In this hypothetical example the depression probably can not be explained by intake loss alone.

3.2 Estimating Increases and Decreases in Standing Stocks.

We estimate increases and decreases in abundance near SONGS as follows. We assume that SONGS changes density to a fraction of the density that would occur if there were no plant. Thus, we are interested in S, the multiplicative effect of SONGS' operation, where the observed density of fish, N, is given by $N = S \times E$, and E is the expected density of fish if there were no losses due to SONGS. S is estimated by:

$$S = (\text{Impact}_A * \text{Control}_B) / (\text{Impact}_B * \text{Control}_A), \quad (1)$$

where, for example, Impact_A is the mean density of fish at the impact area during the After period. This estimator is derived, and explained in greater detail in Final Technical Report J. The change in number caught per set is the difference between what we would have caught in the After period had SONGS not been operating (Expected) and what we actually caught (Observed):

$$\text{Change} = \text{Expected} - \text{Observed} = \text{Impact}_A / S - \text{Impact}_A.$$

The percent change at the impact area relative to the control area equals $(S - 1) * 100\%$.

To obtain the change in numbers of fish for the entire area we assume the local losses apply to, we need to multiply the change in density by the area over which the change is assumed to apply. Our densities are expressed as numbers of fish per set. Above we described the area sampled per lampara seine and otter trawl, and the area over which we assume the observed changes in density have occurred. Before using these numbers to calculate changes in local standing stocks

we need to adjust densities for "catchability" since not all fish within the area sampled by each trawl or seine are caught, as some fish avoid the nets. We use DeMartini *et al.*'s (1987) estimated coefficient of catchability (0.25) for adult queenfish and white croaker for both lampara seines and otter trawls. This estimate of catchability is fairly unreliable; it could easily be off by a factor of 2.

A hypothetical numerical example will help to explain our calculations. Say the following mean catches of queenfish per lampara seine were observed:

Impact _B	50
Control _B	50
Impact _A	100
Control _A	200

Then, $S = (100 * 50) / (50 * 200) = 0.5$. That is, we captured half as many fish per set at Impact in the operational period as we would have had SONGS not been operating. The relative percent change was $(S - 1) * 100\% = -50\%$, or a 50% relative decline.

So, the change in catch per set is

Observed catch/set at Impact _A =	100
Expected catch/set (= Observed/S)=	200
Change per set =	-100

We caught 100 fewer fish per set than we would have had SONGS not been operating. Adjusting for catchability, there would have been 400 more fish in the area sampled by a set (i.e., $100/0.25$). For lampara seines the area sampled per set

is 0.0046 km², and the losses are assumed to occur over a 8 km² region. We therefore multiply the loss of 400 fish per 0.0046 km² by 1736 (8/0.0046) to obtain the losses over the 8 km² region. Thus in the entire impacted area there were approximately 694,000 (= 400 * 1,736) fewer fish than there would have had SONGS not been operating.

3.3 Estimating Inplant Loss of Immatures

We have no direct measure of inplant loss of immatures. We estimate inplant loss of immatures by working backwards from an estimated daily inplant loss of age 1 yr fish (i.e., the number fish entrapped per day that were 365 days old) taking into account how survival and entrapment rates are likely to change with age. Note that mortality and entrapment rates are higher for younger fish.

Let N_{365} be the number of entrapped fish per day that are "exactly" 365 days old (i.e., >364.5 and < 365.5), and S_i equal the daily survival rate for immatures of age i days. E_i is the entrapment rate (assuming fixed densities of fish in the environment) at age $i-1$ expressed as a fraction of the entrapment rate for age i day old fish. E_i is essentially a measure of the rate of change with age of susceptibility to entrapment for immatures of age i days. In practice we assume E_i does not vary with age. Thus we assume that susceptibility to entrapment falls off exponentially with increasing age, following the assumptions of Final Technical Report D.

To simplify let $f_i = (S_{365-i} * E_{365-i})^{-1}$. Then the total daily number entrapped, over ages 365 - k to 365 - 1 days is given by:

$$T_k = N_{365} (f_1 + f_1 * f_2 + f_1 * f_2 * f_3 + \dots + f_1 * \dots * f_k). \quad (2)$$

An explanation of equation (2) is as follows. Consider, for example, age 364 day fish. To determine the rate (numbers per day) at which fish of this age are taken into the plant we first multiply N_{365} by $1/S_{364}$ because there will be $1/S_{364}$ as many age 364 day fish as there are age 365 day fish in the environment and at risk. We then multiply this result by $1/E_{364}$ because at a given density of fish the entrapment rate of age 364 day fish will be $1/E_{364}$ times larger than it is for age 365 day fish. Thus, the entrapment rate of age 364 day fish is estimated by

$$N_{364} = N_{365} * [1/(S_{364} * E_{364})] = N_{365} * f_1.$$

Similarly $N_{363} = N_{364} * f_2 = N_{365} * (f_1 * f_2),$

and $N_{365-i} = N_{365-(i-1)} * f_i = N_{365} * (f_1 * f_2 * ... * f_{i-1} * f_i).$

Thus our formula for T_k simply states that the total number entrapped per day is the sum of the number of each age entrapped. T_k is sensitive to N_{365} , S_i and E_i (all of which are rough estimates): T_k could easily be off by a factor of 2.

We use an equation from Parrish (presented at CalCOFI 1977) to estimate daily survival (S_j). Parrish showed a strong relationship between length (L) in cm and annual natural mortality (M):

$$M = C * L^{-k}, \text{ where } C = 33.916 \text{ and } k = 1.1177 \quad (3)$$

Parrish used eggs, larvae and adult fish from different species in establishing this relationship. We calculate M_j , the mortality for a fish aged j days, by estimating L_j , the average length of such fish from estimated daily growth rates, and substituting this estimate into Parrish's equation. We then convert this mortality into a daily survival by the formula $S_j = \exp(-M_j/365)$. We know of no direct estimates of mortality rates of juvenile queenfish and white croaker, much less as a

function of size or age. This equation appears to provide a reasonable fit to mortality rates over the size range of juvenile queenfish and white croaker. Of course, the mortality rate of queenfish and white croaker may differ substantially from that "expected" of fish of their size, and this adds uncertainty to our estimates of juvenile entrapment rates.

4.0 EVALUATING WHETHER MIDWATER DEPRESSIONS CAN BE EXPLAINED BY INTAKE LOSSES

We begin by estimating local depressions in standing stocks and by estimating inplant losses of juveniles. We then use this information, together with the simple model presented in Section 3.1 to evaluate whether inplant losses can explain local reductions in the standing stocks. We follow this procedure first for queenfish (Section 4.1) and then apply it to white croaker (Section 4.2).

4.1 Queenfish

4.1.1 Estimating the Local Depression in Standing Stock of Immature Queenfish

Lampara catch of queenfish was divided into immatures and adults for BACIP (Interim Technical Report 3). Ten cm is approximately the length at age 1 yr, and we used this length as the break-point between immatures and adults.

For immatures we combined all four stations in the Impact area since density declined at each. The estimated mean catches per seine of immatures in the Impact and Control areas in the Before and After periods were:

	Impact	Control
Before	74.6	88.6
After	22.8	50.6

Assuming catchability is the same in the Before and After periods, $S = [(22.8)(88.6)]/[(74.6)(50.6)] = 0.54$, based on equation (1). The relative percent change = -46%.

In order to convert this loss to number of immature fish per area sampled by a seine, we needed to adjust for catchability of immatures. In the Before period, the mean catches of immature and adult queenfish were approximately equal. For Control and Impact stations, the average catch of immatures was 81.6 and the average catch of adults was 74.5. Given equal catchabilities, we would expect to have caught more immatures than adults, assuming the time spent in each stage was the same. The fact that we did not strongly implies that catchability for immatures is less than that for adults. In the following we estimate a separate catchability coefficient for immatures.

Based on estimates of natural mortality (using equation (3), Section 3.2) we estimate that the observed catch of older immatures, immatures (> 60 mm), should have been about 2 times more than observed if catchability of this stage were the same as it was for adults. Thus catchability of immatures was about half that of adults. We reached this conclusion as follows. Lampara caught adults have a mean length of a little under 12 cm and are about age 1 yr + 110 days. (Entrapped adults range in length from 10 cm to about 20 cm.) Older immatures have a mean length of a little more than 8 cm, and are about 80 days younger than 1 yr. (Note, immatures as small as 3 cm in length were caught but catches of fish less than 6 cm in length are low.) Early adults grow at approx 0.018 cm/day. Immatures grow at 0.024 to 0.025 cm/day. We base these estimates on data and figures in Demartini *et al.* (1987), Interim Technical Report 3, and Final Technical Report D. Based on these growth rates we calculated age at length over the size range 8 cm to 12 cm. We used equ. (3) to estimate mortality as a function of size and hence age. Based on these calculations we estimate that approximately half the fish that are alive at 8 cm in length survive to be 12 cm in length. Thus, on average, there should be half as

many 12 cm long queenfish as 8 cm long queenfish. Consequently, since about as many older immatures were caught as adults, we estimate that the catchability for older immatures was 1/2 that for adults, i.e., 0.125.

As mentioned above, the catch of queenfish less than 6 cm in length fell off sharply. Based on the following calculations we estimate that about 5 times as many younger immatures (3 cm to 6 cm) as older immatures (6 cm to 10) should have been captured if catchability for the two stages was the same. Using equation (3), and the estimated growth rate of immatures, we compute the total number of immatures surviving from age 77 days (3 cm) to 365 days (10 cm) starting with some arbitrary number of 77 days-old queenfish. We then divide the total survivors for 3 cm to 6 cm by the total number for 6 cm to 10 cm. This quotient equals about 5.

Given that catches in the Before period were approximately the same for immatures and adults, then the catchability for all immatures is 1/12th ($1 / (2 + 2*5)$) that for adults, i.e., 0.021.

For older immatures:

Observed catch/set at Impact _A =	22.8
Expected catch/set (= Observed / S)=	42.2
Change per set (diff.)=	-19.4

For older immatures only, adjusting for catchability (1/0.125) and taking into account the assumed area impacted (8 km²), the decrease in standing stock is estimated to be 270,000 fish. For all immatures, adjusting for catchability (1/0.021) and taking into account the area assumed to have been impacted, the decrease in

standing stock is 1,600,000 fish. Here we assume that the depression ($S = 0.54$) estimated for older immatures holds for younger immatures also.

4.1.2 Estimating the Inplant Loss of Immature Queenfish

In Final Technical Report D it was estimated that entrapment rates for a given aged preadult queenfish were 98.2% of the rate for fish one day younger.¹ This provides our estimate of 0.982 for E_i , which applies to all ages of juveniles. We estimate N_{365} as follows. In Final Technical Report C it was estimated that the annual loss of queenfish to Units 1, 2 and 3 (including impingement, heat treatment and mortality during diversion) equals 640,000 fish. This equals 1,700 queenfish/day. Based on Interim Technical Report 3, Figure 4, we estimate that approximately 4% of all entrapment losses are for 9.75 cm to 10.25 cm queenfish, which equals approximately 70 queenfish/day. The 9.75 to 10.25 interval represents about 20 days of growth. So, there are approximately 3.5 (70/20) "exactly" one year old queenfish entrained/day, and this provides our estimate of N_{365} . Using equation (2) from Section 3.2, with mortality rate estimated from equation (3) of that section, we compute T_k for the following days in age less than age 1 yr.

Days before age 1 yr (k)	Intake Loss Per Day (T_k)
50	360
100	1,700
150	7,200
200	32,000
250	170,000
288	700,000
300	> 1,000,000

¹ Changes in the final version of Technical Report D may alter this value slightly, but will not affect the conclusions of this analysis.

At 288 days before age 1 yr (metamorphosis), $T_k = 700,000$. As mentioned in Section 3.2, T_k is sensitive to N_{365} , S_i and E_i -- all of which are fairly crudely estimated; T_{288} could be off by a factor of 2, as low as 350,000 or as high as 1,400,000.

4.1.3 Estimating the Local Depression in Standing Stocks of Adult Queenfish

As with immatures, we've combined all four stations at Impact since all show declines. The estimated catches per set in the midwater in the Impact and Control areas in the Before and After periods for adult queenfish were:

	Impact	Control
Before	97.4	51.6
After	30.9	52.6

From equ. (1), $S = 0.31$, and the relative percent change = -69%. We calculate the loss in number of fish per set as:

Observed catch/set at Impact _A =	30.9
Expected catch/set (= Observed / S) =	100.0
Decrease per set (diff) =	-69.1

Adjusting for catchability (1/0.25) and taking into account the total area we assume the depression applies to (8 km²), the decrease in standing stock is estimated to be 480,000 fish.

4.1.4 Estimating the Inplant Loss of Adult Queenfish

Based on the annual loss of queenfish reported in Final Technical Report C (see above) we estimate the daily inplant loss of queenfish to be 1,700/day. Approximately 40% of these are greater than 10 cm (based on their Figure 7), or 700 adults per/day.

4.1.5 Evaluating Whether the Inplant Losses can Explain Depressions of local Midwater Standing Stocks of Queenfish.

In this section we use the methods presented in Section 3.3; we require estimates of N_p (the population size in the impact area, if unaffected by SONGS), N_o (the population size in the impact area, once affected by SONGS), and sN_o the daily inplant loss. From these we estimate the mean residence time, $1/c$ (where $c = sN_o / (N_p - N_o)$). This mean residence time ($1/c$) is a measure of how fast fish would need to move out of the impact area to explain the depression, given the estimated daily inplant loss.

4.1.5.1 All Immature Queenfish

For all immature queenfish, $N_p - N_o = 1,600,000$ fish (Section 4.1.1), and $sN_o = 700,000$ immature fish/day (Section 4.1.2).

$$c = sN_o / (N_p - N_o) = 0.437.$$

The mean residence time required to explain the depression is $(1/c)$ or about 2.3 days. Inplant loss appears adequate to explain the depression of all immatures.

This result is driven largely by the younger immatures which are much more likely to be taken into the plant. We next consider older immatures separately.

4.1.5.2 *Older Immature Queenfish*

For older immatures only, $N_p - N_o = 270,000$ fish (Section 4.1.1). $sN_o = 12,000$ older immature fish/day (this from Section 4.1.2, T_k for $k = 160$).

$$c = sN_o / (N_p - N_o) = 0.044.$$

The mean residence time required to explain the depression is $(1/c)$ or about 23 days. This number is large enough so that inplant losses may not explain the local depression, but not so large that we can rule this possibility out. Our best estimate of the residence time needed to explain the depression seems a bit on the high side, but given the lack of precision of the estimates used in the calculations it is possible that the required residence time is substantially less than our best estimates. For example, the residence time needed to explain the depression equals only three days if we halve the estimated percent change to -23% (from -46%), double catchability to 0.25 (from 0.125), and increase inplant loss by 50% to 18,000/day (from 12,000/day). All these adjustments are well within bounds of statistical precision for the estimates. It is also conceivable that the average residence time of these fish within the Impact zone is as high as 23 days, although this would require the fish to maintain their position along this relatively small area of the coast.

4.1.5.3 Adult Queenfish

For adults, $N_p - N_o = 480,000$ fish (Section 4.1.3). $sN_o = 700$ fish/day (Section 4.1.4).

$$c = sN_o / (N_p - N_o) = 0.0015.$$

The mean residence time required to explain the depression is $(1/c)$ or about 667 days. This seems too high since it requires individual fish to remain within an extremely restricted area on the open coast for a significant portion of their lifespan. Inplant loss probably cannot explain the depression of adults. Even if the estimates used in the calculations are off by a wide margin, the residence times required to explain the depression seem high. For example, the residence time required to explain the depression is still 55 days when we halve the estimated percent change to -34.5% (from -69%), double catchability to 0.50 (from 0.25), and increase inplant loss by 50% to 1,050/day (from 700/day).

4.2 White Croaker

4.2.1 Estimating the Local Depression in Standing Stock of White Croaker

The data for white croaker pose two problems. First, the size composition of lampara catches at Impact and Control sites is different for Before and After periods: for the Before period the modal size was about 13 cm and in the operational period it was about 5 cm (see DeMartini *et al.* 1987, Appendix E, Figure 52). Since one year old fish average approximately 11 cm in length, most fish caught in the Before period were adults and most fish caught in the After period were

immatures. Hence, the observed depression results from relatively fewer immatures at the Impact than at the Control area, and not from a relative decrease in adult density. BACIP analyses and the following calculations assume that the multiplicative effect of SONGS' operation is the same for immatures and adults.

Exactly which stations to include in estimating the size of the depression poses the second problem. For the BACIP analysis (Interim Technical Report 3) the shallow impact sites showed significant relative declines while the deep impact sites showed relative increases, though these were not significant. Further, the significant change at the far shallow site was at the 0.06 level and the assumption of additivity was satisfied by adding a constant of 10 prior to taking the logarithm. The relative percent changes from BACIP analyses were:

	BACIP: Relative % Change
Near Shallow	-63%
Far Shallow	-36% to -54%

Based on the computations for S (Section 3.2), the relative percent changes were:

	S: Relative % Change
Near Shallow	-71%
Far Shallow	1%

The results for relative percent change are similar at the near shallow site. But for the far shallow site the estimated relative percent change is very different from that for BACIP -- largely because BACIP was performed on means of log-transformed data, with a constant of 10 and many zero observations.

Mean catches at the far shallow site were similar in the Before and in the After periods. The mean catches at the shallow station of the far impact area and at the control station were:

	Mean Catch	
	Impact	Control
Before	77.1	67.9
After	27.4	23.9

This method of analysis does not support the conclusion of the BACIP test, and suggests that there may not have been a real decline at the far-shallow impact location. In computing the depression we use only the near shallow site, and we assume an impact area of 2 km² (see also Section 2).

Using the near shallow impact station, the estimated catches at Impact and Control stations in the Before and After periods were:

	Impact	Control
Before	18.6	67.9
After	1.9	23.9

and $S = 0.29$, Percent relative change = -71%.

Hence for (immature) white croaker:

Observed catch/set at Impact _A =	1.9
Expected catch/set (= Observed / S) =	6.4
Change per set (diff.) =	-4.5

Adjusting for catchability ($1/0.021$) and taking into account the area assumed to be impacted (2 km^2), the decrease in standing stock is estimated to be 93,000 fish. In this calculation we use the same catchability we estimated for immature queenfish.

4.2.2 Estimating Inplant Loss of White Croaker

We estimate inplant losses of white croaker using the methods outlined in Section 3.2, as we did for queenfish in Section 4.1.2. To do this we need estimates of E_i and N_{365} . Our estimate of E_i is 0.972, which applies to all ages of juvenile white croakers, and comes from Final Technical Report D.² This is the entrapment rate of age $i-1$ day old fish as a fraction of the entrapment rate of i day old fish.

We estimate N_{365} as follows. The annual loss to Units 1, 2 and 3 (including impingement, heat treatment and mortality during diversion) is estimated to be about 100,000 fish (Final Technical Report C). Thus 275 white croaker are killed per day. Based on Figure 6 of that report we estimate approximately 4% of all inplant losses are for fish in the 10 cm to 12 cm length range. Thus, in this length interval 11 white croaker are killed per day. The 10 cm to 12 cm interval represents about 70 days of growth. So, there are approximately 0.16 ($11/70$) "exactly" one year old white croaker entrained/day, and this is our estimate of N_{365} . Using equation (2) we calculate:

² Changes in the final version of Technical Report D may alter this value slightly, but will not affect the conclusions of this analysis.

Days before age 1 yr (k)	Intake Loss per day (T_k)
50	23
100	160
150	1,100
200	8,000
250	71,000
275	240,000
300	>800,000

At 275 days before age 1 yr, the age at metamorphosis, $T_k = 240,000$. As mentioned in Section 3.2, T_k is sensitive to N_{365} , S_i and E_i -- all of which are fairly crudely estimated; T_{275} could be off by a factor of 2, as low as 120,000 or as high as 480,000.

4.2.3 Evaluating whether Inplant Losses can Explain Depressions of Local Midwater Standing Stocks of White Croaker.

As discussed in the introduction to Section 4.0, we use a simple model to evaluate whether local depressions in standing stocks can be explained by inplant losses (see also Section 3.1).

For white croaker, $N_p - N_o = 93,000$ (immature) fish (Section 4.2.1), and $sN_o = 240,000$ (immature) fish/day (Section 4.2.2).

$$c = sN_o / (N_p - N_o) = 2.6.$$

The mean residence time required to explain the depression is $(1/c)$, or less than 1 day for the 2 km² impact area. Inplant losses are clearly adequate to explain the estimated local depression of white croaker.

5.0 SUMMING DECREASES IN THE MIDWATER AND INCREASES ON THE BOTTOM

Here we ask whether there has been a net increase or decrease in standing stock when decreases detected in the midwater are combined with increases detected on the bottom. Above (Section 4) we estimated the decline in the local standing stock in the midwater populations sampled by lampara seine. Here we estimate the increase in the standing stock of the bottom oriented population sampled by otter trawl and combine that estimate with the estimate of change for the midwater, after correcting for differences in size (and hence age) distributions between the two populations. Note that otter trawl catches were not divided into immatures and adults.

5.1 Queenfish

We first estimate the increase in standing stock on the bottom as sampled by otter trawls. We combined 18 m and 30 m stations at both Impact and Control locations. The estimated catches at Impact and Control for the Before and After periods were:

	Impact	Control
Before	7.8	11.3
After	11.2	9.4

$S = 1.72$, and the relative percent change was 72%. We calculate the losses in numbers of fish per set as:

Observed catch/set at Impact _A =	11.2
Expected catch/set (Observed / S) =	6.5
Change per set (diff.) =	4.7

Adjusting for catchability (1/0.25) and taking into account the area the increased density was assumed to have occurred in (4 km²), the estimated increase in abundance is 80,000 fish.

In combining this increase with the decrease calculated earlier we are combining the decrease in numbers of lampara caught older immatures plus adults (lampara seine) with the increase in numbers of otter-trawl caught adults. We do not include early immatures for two reasons: (1) their depression is not based on direct estimates of changes in density since very few were caught, but instead is extrapolated from losses of older fish, and (2) the estimated depression is imprecise, (a) being based on rough estimates of mortality, entrapment rate and daily inplant loss and (b) is extrapolated backwards in age 288 days.

Fish caught with otter trawl were older than fish caught with lampara seine, based on the observation that on average, otter trawl caught fish weigh more than lampara caught fish. The age difference is approximately one year. In order to compare lampara and otter trawl catches, we correct for the mortality that would have occurred to lampara caught fish over one year: approximately 50%. The corrected depression in the following is computed by halving the summed depressions of older immatures (Section 4.1.1) and adults (Section 4.1.3).

Corrected Depression	-375,000
Increase	80,000

The weight of the evidence points towards the depression exceeding the increase. Even if 75% mortality occurs during the time it takes to develop from the size seen in the midwater to the size seen on the bottom, the depression, corrected for this higher mortality rate, still exceeds the increase by over 100,000 fish.

5.2 White Croaker

Again we start by estimating the increase based on otter trawls, and then combine this estimate with the estimated decrease based on lampara seines calculated earlier. Again we combined 18 m and 30 m stations at both Impact and Control.

The estimated otter-trawl catches at Impact and Control for the Before and After periods were:

	Impact	Control
Before	32.9	52.0
After	20.2	9.5

$S = 3.36$ and the relative percent change is 236%.

We calculate the loss in number of fish per set as:

Observed catch/set at Impact _A =	20.2
Expected catch/set (= Observed / S) =	6.0
Change per set (diff.) =	14.2

Adjusting for catchability of adult white croaker (1/0.25) and taking into account the areas assumed to be impacted (4 km²), the increase in standing stock is estimated to be 239,000 fish.

As with queenfish, otter trawl caught white croaker were older than those caught with lampara, again based on the observation that on average, otter trawl caught fish weigh more than lampara caught fish. The age difference is slightly over one year -- in the After period, lampara catches were of younger immatures. In order to compare lampara and otter trawl catches, we correct for the mortality that would have occurred to lampara caught fish over this year: approximately 50%. The corrected depression is computed by halving the depression reported in Section 4.2.1.

Corrected Depression	-46,500
Increase	239,000

The weight of evidence points towards the increase exceeding the depression. Even if we do not correct for the different ages of fish the increases and decreases apply to, the increase still exceeds the depression by more than 100,000 fish.

6.0 SUMMARY AND DISCUSSION

We attempted to determine whether inplant losses can explain the observed local depressions in standing stocks by looking at the mean time that a fish would be required to remain within the impact areas in order to explain the depressions. The higher the mean residence time, the less likely it is that inplant loss can entirely explain the depression. The estimated mean residence times required to produce the observed depressions are:

	Mean Residence Time
All Immature Queenfish	2.3 days
Older Immature Queenfish	23 days
Adult Queenfish	667 days
White Croaker	less than 1 day

For all but adult queenfish we feel, given the many assumptions that have gone into these calculations, and the almost complete lack of information regarding normal residence times of these fish, that intake losses can reasonably explain the depressions in standing stocks. We stress that the exercise we have gone through in this report does not preclude other mechanisms from operating, it simply indicates that such other mechanism need not be invoked to explain the estimated depressions. It appears however that losses of adult queenfish cannot be explained by intake losses unless these midwater fish remain in a relatively small area for much longer time periods than is generally believed to be the case.

Turning now to the second question addressed here, the weight of the evidence points towards a net decrease for queenfish (older immatures plus adults) and a net increase for white croaker. Our estimates of the increases and decreases are:

	Increase	Corrected Decrease
Queenfish	80,000	-375,000
White Croaker	239,000	-46,500

The decreases are corrected for mortality that would have occurred over the year between the age of lampara caught fish (decrease) and age of otter-trawl caught fish (increase). Although these estimates are relatively imprecise, the very large differences in the sizes of the increases and decreases adds to our confidence in the conclusion that there has been a net adverse effect on queenfish and a net positive effect on white croaker.

We remind the reader that the impact areas are unknown, although the ones we use in our calculations are based on reasonable assumptions. The calculations and conclusions of this report are consistent with the assumptions that (1) net decreases in abundance occurred only in the nearshore area adjacent to the intakes where lampara samples were taken, (2) net increases occurred only near the bottom in offshore area where the benthos is most likely to be biologically enriched by SONGS' effluent, and (3) impacts were assumed to be restricted in the longshore direction as specified in each calculation.

We believe that our assumed area of impact is reasonably well supported for the midwater decline of white croaker. This is because there were no decreases at the far-shallow and both deep water lampara seine sampling stations that were outside of our assumed impact area. We have no data with which to evaluate our other assumed impact areas. It is possible that the increases observed on the bottom in 18 - 30 m of water extended further up and downcoast and into deeper depths than we assumed. It is also possible that at these depths increases extended into the water column and were not restricted to the bottom. We have no direct evidence for or against these possibilities. Our assumed areas in which the increases occurred are based on the proposed mechanism of food enrichment, and the assumption that this effect will be restricted to the bottom at depths less than 30 m, and to within 1 km of the diffusers. Although we know that some benthic invertebrates (potential food) did increase in abundance at distances further than 1 km from the diffusers, it is also clear that the increases in soft bottom dwelling invertebrates were most marked within approximately a kilometer of the diffusers, and that increases probably did not extend as far upcoast as they were observed to extend downcoast.

It is also possible that the decreases observed for queenfish in the midwater extend further from the plant and to deeper depths than we have assumed. Because the intake is in 8 m of water, and increases were seen on the bottom in deeper water, we made the assumption that declines did not extend into deeper water. We have no evidence one way or the other regarding the possible extension of the queenfish depression further from the intakes than 2 km. If the depression does extend further than we have assumed, and the increases on the bottom do not, this would lead to a larger adverse effect than we have estimated. The existence of such

a larger impact area for queenfish would also make it less likely that the observed depressions of adults and larger juveniles could be explained by inplant losses. However, our qualitative conclusions of a net adverse effect on queenfish, and the need for additional mechanisms besides inplant losses to explain local depressions in standing stocks of adult queenfish remain.

7.0 REFERENCES

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