TO: Hope Smythe, Executive Officer
Santa Ana Regional Water Quality Control Board

FROM: Professor Pete Raimondi, University of California, Santa Cruz

DATE: March 5, 2019

SUBJECT: APPROACHES FOR THE ASSESSMENT OF POTENTIAL INTAKE LOCATIONS WITH RESPECT TO ENTRAINMENT, PROPOSED HUNTINGTON BEACH DESALINATION PLANT

This memo is to give some context and guidance to the assessment of potential intake sites for the Huntington Beach Desalination Plant (HBDP). There are 6 alternative sites being evaluated, in addition to the proposed intake site (station E). These are sampling locations that were used to assess the concentration of larvae in the Sample and Total Source Water Bodies during earlier evaluations to determine the impact of once-through use of water for power generation and desalination. The early evaluations were focused only on the entrainment effects of the intake located at station E. Though all the stations were used to characterize the source water body, and much of the data were collected using identical methods at all seven stations, data for some stations were much more limited than that collected for station E. In particular, there were very limited larval length data collected at any station other than station E. This has major implications for the primary approach used to assess impacts relating to entrainment (Empirical Transport Model/Area of Production Foregone, ETM/APF) as discussed below. Because this previous ETM/APF analysis was not conducted to compare entrainment at different sampling stations within the study, and therefore the data at the 6 alternative sites is limited, we are developing a novel approach that relies on multiple lines of evidence to provide a method to compare entrainment effects among alternative stations. First, I will provide a quick review of the problems associated with the use of ETM/APF for the purpose of station comparison that is unique to this assessment, then I will describe the proposed hybrid approach.

Background on ETM/APF

ETM/APF has been the primary tool for the evaluation of entrainment impacts in California for almost two decades. Over that period there has been an evolution of some of the model elements, but the core equations have remained the same. The details of the approach have been laid out and reviewed elsewhere; however, I will review the basic ideas for the model and indicate why the use of it is problematic in this specific case.

The general idea of the model is to evaluate risk to a population of a species due to mortality caused by some source. Here, we are talking about entrainment. Risk is defined as the proportion of the vulnerable population (Pm) that is killed as a result of entrainment. Calculating Pm across species representative of the local community leads to the ability to assess

community-wide risk and also, through APF, to convert that risk into a measure of compensatory mitigation. It is a robust approach in that it should allow for community-wide assessment of direct and indirect impacts related to entrainment. As such, it should be an appropriate approach for the comparison of ecological impacts at potential intake locations.

What is needed, in a general sense, in order to use the ETM/APF approach to assess impact potential is: (1) Site specific measurements of concentration of larvae entrained, (2) Site specific estimates of age frequency distributions for representative species and (3) Site specific information concerning hindcast probabilities of larval delivery from locations in the source water body to the station (typically based on current information). These three factors in combination allow for a more complete characterization of the source water body population (i.e. the population at risk to entrainment). Age of larvae is based on size of the larvae (usually determined by the length of the larvae). Generation of age frequency relies on a sufficient number of larvae being measured for length. For the evaluations available for HBDP, there are scant measurements of larval length (age) for any station other than station E, which limits ETM/APF calculations at other stations. These components can be mathematically assembled to provide both Pm and APF values. If a study was designed to compare stations, estimates for # 1, 2, and 3 above would be needed for all potential sites.

For HBDP, an attempt has been made to use data collected in 2003-2004 as part of the California Energy Commission (CEC) impingement and entrainment study for the AES Huntington Beach Generating Station (HBGS) Retool Project (MBC and Tenera, 2005). Seven stations were selected as larval sampling sites to characterize the source water body for the generating station's intake, which is located near station E. This study provided good characterization of site-specific larvae concentrations (# 1), but no site specific information about larvae delivery (#3), and very little information concerning age frequencies (#2). In addition, the oceanographic instrument that could have provided simultaneous ocean current speed data for the general area failed (#3) and therefore, ocean current information for a different time period (1999-2000) were used.

Based on these deficiencies, it was clear that we should not rely solely on ETM/APF to make the station comparison. Instead, an approach was adopted to look at other "lines of evidence" that together might inform the comparison. The ones discussed below are all quantitative; another set is largely qualitative and will not be discussed here.

The three quantitative approaches are: (1) using ETM/APF with an understanding of the limitations in this particular case, (2) looking at raw estimates of station-specific larval loss, which is estimated as the mean larval concentration at each station, and (3) standardized species-specific loss. Approach #2 provides a way to assess station-specific comparison of total larval loss irrespective of species. Here, species contribute to the estimated loss in proportion to their abundances. In Approach #3, each species' concentrations are standardized across stations such that all species count equally, whether they were common or rare in the samples.

APF: here are many issues with this approach given the available data. First, there are limitations with respect to species that can be assessed because of the deficiency in larval length data (in the form of size frequency data) for all stations other than station E. For station E, 12 species are available for use, including the 9 species sufficient to assess impact in the 2005 HBGS impingement and entrainment study. For all other stations, there are no more than 4 species that are common to all seven stations. This number of species would likely not be sufficient for a stand-alone impact determination. Moreover, my initial review suggests that the overall APF at station E decreases with increasing sample size. This means that a comparison among stations should rely on these common 4 species (meaning that the calculation for station E should also be based on the common 4 species and not 12).

The second issue concerns current measurements. Normally, the larval delivery function (#3 above) is calculated using ocean current speed data collected during the larval sampling period. In this case, we have 2 types of current speed data. The first is based on a single estimate for all stations in each of two time periods (1999-2000 and 2007-2008), which are both outside the time period when the larval population was sampled (2003-2004). Although neither time period is likely to match the current regime that occurred during the 2003-2004 larval sampling, both estimates were used as representative speeds for the nearshore area. The second set of estimates is site specific and is based on Regional Ocean Modeling System (ROMS) output for the appropriate time period. These are values modeled in a grid of spatial cells. However, there is concern about modeling at nearshore stations as they are located outside the nearest modeled cells. Here, ROMS estimates were projected from nearby cells. These values should also be used to provide APF estimates.

Finally, there are two estimates for estuarine species (CIQ gobies and Diamond Turbot) larval concentrations: one set collected from Agua Hedionda Lagoon (AHL) and the other from Alamitos Bay (AB).

Because the ETM/APF evaluation for station comparison is based upon sampling designs implemented for other reasons– i.e., to determine entrainment risk at a single location rather than to compare entrainment risks among several locations – an approach for combining all values is preferred. The key is to provide a single reconciled set of APF estimates--one for each station. My recommendations for this approach are:

1) Produce one set of values (APF) for the ROMS-based current measurements and another set for current measurements based on area estimates (from single point current measurements from the two sample periods, 1999-2000 and 2007-2008).
    a. The area values for the area estimates can be derived as the average of the two sets representing the two periods.
2) For species with estuarine populations (CIQ gobies and diamond turbot), the calculation of Pm is based on two source water populations – the nearshore open coast (as for the

other species) and also estuarine subtidal habitat adjacent to nearshore source water bodies. Concentration of larvae for these species in the nearshore can be estimated based on sampling done at stations during the 2003-2004 evaluation. However, there was no directed sampling of estuarine populations in the HBGS impingement and entrainment study and hence other information must be used to estimate likely estuarine concentrations. There are two sources of such information, as previously noted. Measurements of larval concentrations of CIQ gobies and Diamond Turbot from both AHL and AB can be used to estimate estuarine source water concentrations for these two species.

3) Combining #1 and # 2 entails:
    a. For each species and station - calculating APF values using AB and AHL larval concentrations for the three current estimates (ROMS, 1999-2000, 2007-2008)
    b. Given a, for each species and station – calculating the average APF across the two non-ROMS models (1999-2000 and 2007-2008).
    c. Given a and b, for each station and species – calculating the average APF of the non-ROMS (b) and ROMS model. This will result in a single estimate of APF per station and species--the "joint estimate" (Equation 2, below).

ETM/APF has been the modeling approach used in almost all recent evaluations for estimating entrainment loss from once-through cooling use of seawater in California for power generation stations. Its key advantage is that it provides simultaneous estimation of species vulnerability (i.e. risk) and a currency relevant to mitigation (area of production foregone = area of habitat which, if restored or created, would provide compensatory mitigation). The utility of this approach relates directly to the adequacy of the data collected, particularly with respect to representation of species (and species life histories) likely to be affected. When ETM/APF approaches are planned in advance of a potential study, data adequacy is integrated into the sampling design. Here, ETM/APF is being used for stations (all but E) that were not envisioned as potential intake locations; hence, there are severe constraints on the species for which the approach can be used. This compromises the utility of this approach because we are limited to 4 species for which there is minimally sufficient information for the core calculations. However, if the purpose of the study had been to compare potential entrainment among all of the larval sampling stations, the ETM/APF approach with adequate sampling at each station would have been the preferred option.

Mean Larval Concentration (MLC): This is a very simple approach (this is one of its attributes). The goal is to get an estimate of the larval loss by station. Given that the intake volume is constant (meaning that whatever the actual volume, it will be the same at all stations), what is needed is the mean larval concentration over the entire sampling period for each station. These overall MLC estimates should not be species specific. As an example, there are species-specific estimates of larval concentration for each station over 12 surveys. Within each survey there are 4 cycles of sampling and 2 replicates in each cycle. This means that there are 8 estimates of larval concentration (# per cubic meter) for each survey / station combination. It is important to

note that the datasets are not populated with zeros, so zeros need to integrated back into the data. The mean concentration per station can be attained by summing concentrations across species (but maintaining Station, Survey, Cycle and Replicate as strata), then calculating the mean for each station.

The core idea that is the basis of the use of MLC is that one aspect of determining ecological impact is simply to calculate the total larval loss per proposed intake station. The station with the lowest projected total entrainment, if species-specific risk is assumed to be not important, could be considered the station having the lowest ecological impact with respect to entrainment. Here we are using this as one of three approaches and note that the other two approaches both are based on species specific risk.

Standardized Larval Concentration (SLC): As noted above, this approach is based on station and species-specific larval concentrations. However, the values are then standardized such that all species count equally irrespective of whether the species was common or uncommon in the samples. In previous discussions, we discussed the use of Z-scores which are distributed as a normal deviate (typically ranging between -3 and 3) based on the following equation: Z=(measurement-mean)/standard deviation. This will be done for each species and the replicates are stations. The key here is to define the constraints on the values. For example, this could be done for each sampling period. As an example, the mean and standard deviations for goby concentrations for sample period 1 could be calculated across stations and used to calculate species-, sample-, and station-specific Z values. One underlying assumption of doing this is that the pattern of larval abundance over time is unimportant. This is because a period with low concentrations would count equally to one with high concentrations. This is not the intent of the transformation. Instead, and more simply, the idea is that each species should count equally but that the standardized dataset should be based on the station and species-specific (but not survey, cycle or replicate) mean concentrations of larvae over all sample periods. It is important to note that, as with the MLC approach, the datasets are not populated with zeros, so zeros need to integrated back into the data. The species-specific standardized concentration per station can be attained by averaging the concentrations of each species across Survey, Cycle and Replicate. These values can then be standardized as discussed above.

SLC is a modification of MLC that mathematically equalizes all species. This means that each species counts the same toward an overall estimate of impact. The reason for this is to provide an evaluation of risk, in the absences of a sufficient ETM/APF assessment. It is recognition that uncommon species, which minimally contribute to the MLC, may actually be more at risk to ongoing or new sources of mortality than are common species which drive MLC estimates.

Linking the three approaches: The decision on how or whether to link and weight APF, MLC, and SLC is a policy decision. The argument for linking and perhaps differentially weighting each estimate is based on the idea that all provide independent, or at least semi-independent, estimations of impact. Therefore, linking the estimates provides a more comprehensive

evaluation. Alternatively, if all are essentially designed to evaluate ecological risk, then linking better and worse methods may diminish the accuracy of the evaluation. The key decisions that must be made are 1) whether or not to link, and 2) if not, which metric to use.

If metrics are to be linked, here are some possible approaches:

1) Ranking stations in each approach and then using the mean of the ranks as a final assessment for stations. This assumes all approaches are equally valuable and that ranks (more than measurements) are better indicators of relative value. For example, stations A, B, and C with values 10, 12, and 25 respectively, would be ranked 1, 2, and 3 but the difference among stations is progressive by 2 and 13, meaning station C (25) is much more different from Station B (13) than B is from A (2). Yet, the difference in ranks is the same.

2) Making units comparable but maintaining measurement differences. As one example, all attributes could be converted to a relative scalar using the equation:

$$\frac{y_i - min}{max - min} \qquad (1)$$

   where y_i is the value for station i and *min* and *max* are the minimum and maximum values across stations for the metric of interest. This results in all metrics have a range of 0 -1. This approach ensures no inadvertent weighting of the attributes (because all are scaled 0-1).
3) Some combination of either 1 or 2 but with weighting that represents relative importance in the metrics.

Assessment of potential intake locations with respect to entrainment

I have reviewed submissions by both Poseidon and the CCC. Both contained estimates of potential station-specific entrainment impact based on APF, MLC and SLC. In addition, other metrics (quantitative and qualitative) were provided by both, but primarily by Poseidon. This review does not cover any assessment other than as described above for APF, MLC and SLC. My initial review was an interactive process with both groups to ensure that there was consistency in terms of data (e.g. repopulation of zeros), analytic approaches, and simple QA/QC activities, such that the results from both parties for the core metrics are similar. This means that the values and the approaches taken to get to the values are not different and are consistent with agreed upon approaches and, also, with the values I calculated. Hence, the key issue relates to interpretation of the values. Below I present the final values for both groups along derived metrics (i.e. ranks and scaled values) that can be used in assessing potential entrainment impact at all stations.

Group	Station	Joint APF	MLC	SLC
CCC	D2	146.5948	0.5697	-0.1835
CCC	D4	137.8344	0.8226	-0.2260
CCC	E	215.7184	0.6782	-0.2585
CCC	O2	279.6908	0.4451	0.2172
CCC	O4	202.1039	0.6042	0.6616
CCC	U2	199.4776	0.5415	-0.1483
CCC	U4	168.7313	0.9051	-0.0625
Poseidon	D2	146.5948	0.5697	-0.1989
Poseidon	D4	137.8344	0.8226	-0.2336
Poseidon	E	215.7184	0.6782	-0.2392
Poseidon	O2	279.6908	0.4451	0.2010
Poseidon	O4	202.1039	0.6042	0.7242
Poseidon	U2	199.4776	0.5420	-0.1698
Poseidon	U4	168.7313	0.9051	-0.0839

Table 1: Final estimates by Groups for Joint APF (across all species), Mean Larval Concentration (MLC) and Standardized Larval Concentration (SLC). APF is based on 95% confidence interval.

Table 1 shows the final estimates for Joint APF, Mean Larval Concentration and Standardized Larval Concentration for all species. The calculation for 'Joint APF' was based on the weighting given to each of the three estimates of larval transport. They were weighted using the following equation, which yielded an estimate giving equal weight to the period and ROMS estimates:

$$Joint\ APF = \frac{\left[\left(\frac{APF_{P1}+APF_{P2}}{2}\right)+APF_{ROMS}\right]}{2} \qquad (2)$$

where P1 and P2 are period 1 (1999-2000) and period 2 (2007-2008). I also calculated habitat-

specific APF's for estuarine (CIQ gobies and diamond turbot) and open coast species (white croaker and northern anchovy), shown in Table 2. Here, the idea was to determine if the potential station-specific impact differed as a function of habitat. This could be caused by a number of things, but the most likely is distance from an estuary.

Note that MLC and SLC values are the same in Tables 1 and 2. This is because MLC and SLC calculations were not done separately for open coast and estuarine species.

Group	Station	APF Estuarine Species	APF Open coast Species	MLC	SLC
CCC	D2	12.4740	233.2160	0.5697	-0.1835
CCC	D4	24.3426	186.1041	0.8226	-0.2260
CCC	E	7.1829	361.2893	0.6782	-0.2585
CCC	O2	6.0515	358.5923	0.4451	0.2172
CCC	O4	0.1744	281.1617	0.6042	0.6616
CCC	U2	12.2946	343.6112	0.5415	-0.1483
CCC	U4	9.5539	226.2715	0.9051	-0.0625
Poseidon	D2	12.4740	233.2160	0.5697	-0.1989
Poseidon	D4	24.3426	186.1041	0.8226	-0.2336
Poseidon	E	7.1829	361.2893	0.6782	-0.2392
Poseidon	O2	6.0515	358.5923	0.4451	0.2010
Poseidon	O4	0.1744	281.1617	0.6042	0.7242
Poseidon	U2	12.2946	343.6112	0.5420	-0.1698
Poseidon	U4	9.5539	226.2715	0.9051	-0.0839

Table 2: Final estimates by Groups for Joint APF (across all species) for both estuarine and open coast species, Mean Larval Concentration (MLC) and Standardized Larval Concentration (SLC). APF is based on 95% confidence interval.

Station-specific values for Tables 1 and 2 were related to each other as described above, using ranks and scaling (scaling as shown in equation 1). These are shown in tables 3-6.

Group	Station	Joint APF	MLC	SLC
CCC	D2	2	3	3
CCC	D4	1	6	2
CCC	E	6	5	1
CCC	O2	7	1	6
CCC	O4	5	4	7
CCC	U2	4	2	4
CCC	U4	3	7	5
Poseidon	D2	2	3	3
Poseidon	D4	1	6	2
Poseidon	E	6	5	1
Poseidon	O2	7	1	6
Poseidon	O4	5	4	7
Poseidon	U2	4	2	4
Poseidon	U4	3	7	5

Table 3: Ranks for APF, MLC, SLC for both groups. A rank of 1 indicates the lowest estimated impact for the metric of interest. These ranks are based on the values shown in Table 1.

.

Group	Station	Joint APF	MLC	SLC
CCC	D2	0.0618	0.2709	0.0816
CCC	D4	0.0000	0.8207	0.0353
CCC	E	0.5490	0.5067	0.0000
CCC	O2	1.0000	0.0000	0.5170
CCC	O4	0.4531	0.3459	1.0000
CCC	U2	0.4345	0.2096	0.1198
CCC	U4	0.2178	1.0000	0.2130
Poseidon	D2	0.0618	0.2710	0.0418
Poseidon	D4	0.0000	0.8205	0.0058
Poseidon	E	0.5490	0.5067	0.0000
Poseidon	O2	1.0000	0.0000	0.4569
Poseidon	O4	0.4531	0.3458	1.0000
Poseidon	U2	0.4345	0.2107	0.0720
Poseidon	U4	0.2178	1.0000	0.1612

Table 4: Proportional scaling for APF, MLC, SLC for both groups. Values of 0 and 1 indicate the minimum and maximum estimated impact for the metric of interest, respectively. These values are based on those shown in Table 1.

In tables 5 and 6, values for combined APF are shown. For Table 5, these are the ranks of the average of APFS for estuarine and open coast species. For estuarine species these are the average of the scalar values for estuarine and open coast species.

Group	Station	APF Estuarine Species	APF Open coast Species	MLC	SLC	Combined APF
CCC	D2	6	3	3	3	5
CCC	D4	7	1	6	2	3
CCC	E	3	7	5	1	6
CCC	O2	2	6	1	6	3
CCC	O4	1	4	4	7	1
CCC	U2	5	5	2	4	6
CCC	U4	4	2	7	5	2
Poseidon	D2	6	3	3	3	5
Poseidon	D4	7	1	6	2	3
Poseidon	E	3	7	5	1	6
Poseidon	O2	2	6	1	6	3
Poseidon	O4	1	4	4	7	1
Poseidon	U2	5	5	2	4	6
Poseidon	U4	4	2	7	5	2

Table 5: Ranks for APF, MLC, SLC for both groups. APF ranks for estuarine, open coast and combined ranks across both habitats are shown. A rank of 1 indicates the lowest estimated impact for the metric of interest. These ranks are based on the values shown in Table 2.

Group	Station	APF Estuarine Species	APF Open coast Species	MLC	SLC	Combined APF
CCC	D2	0.5089	0.2689	0.2709	0.0816	0.2742
CCC	D4	1.0000	0.0000	0.8207	0.0353	0.5331
CCC	E	0.2900	1.0000	0.5067	0.0000	0.8711
CCC	O2	0.2432	0.9846	0.0000	0.5170	0.7986
CCC	O4	0.0000	0.5426	0.3459	1.0000	0.0000
CCC	U2	0.5015	0.8991	0.2096	0.1198	1.0000
CCC	U4	0.3881	0.2293	1.0000	0.2130	0.0871
Poseidon	D2	0.5089	0.2689	0.2710	0.0418	0.2742
Poseidon	D4	1.0000	0.0000	0.8205	0.0058	0.5331
Poseidon	E	0.2900	1.0000	0.5067	0.0000	0.8711
Poseidon	O2	0.2432	0.9846	0.0000	0.4569	0.7986
Poseidon	O4	0.0000	0.5426	0.3458	1.0000	0.0000
Poseidon	U2	0.5015	0.8991	0.2107	0.0720	1.0000
Poseidon	U4	0.3881	0.2293	1.0000	0.1612	0.0871

Table 6: Proportional scaling for APF, MLC, SLC for both groups. APF values for estuarine, open coast and combined scalar across both habitats are shown. Values of 0 and 1 indicate the minimum and maximum estimated impact for the metric of interest, respectively. These values are based on those shown in Table 2.

Examination of the results of these multiple metrics and multiple approaches to evaluate the metrics leads to no clear indication of which station would result in the lowest impact due to entrainment. Depending on the metric and whether habitats are evaluated separately or together for APF, four stations have the lowest estimated entrainment impact: D4 for Joint APF (Tables 3, 4), E for SLC (Tables 3, 4 and 5, 6), O2 for MLC (Tables 3,4 and 5,6) and O4 for Combined APF (Tables 5, 6). Importantly, no station has the lowest value for more than one metric. As noted earlier, MLC and SLC estimates are the same in Tables 3 and 5 and also in Tables 4 and 6. Later in the report, I will discuss my assessment of the relative importance of the metrics for the comparison of stations, given the data at hand, but before doing this I'll show the results of a synthetic approach that combines all metrics. These results are based on the ranked and the (0-1) scaled approach and were done for both joint APF and habitat-specific APF.

Table 7 shows the summary values for all combination of approaches for both groups. Here the average value across all metrics is shown. For example, values shown in the cells below:

1. *Ranking 1* are the means of the ranks for APF, MLC and SLC from Table 3.
2. *Ranking 2* are the means of the ranks for APF, MLC and SLC from Table 5, where APF is the combined rank for estuarine and open coast habitats.
3. Scalar 1 are means of the scalar values APF, MLC and SLC from Table 4.
4. Scalar 2 are means of the scalar values for APF, MLC and SLC from Table 6, where APF is the combined rank for estuarine and open coast habitats.

Group	Station	Ranking 1	Ranking 2	Scalar 1	Scalar 2
CCC	D2	2.6667	3.6667	0.1381	0.2089
CCC	D4	3.0000	3.6667	0.2853	0.4630
CCC	E	4.0000	4.0000	0.3519	0.4593
CCC	O2	4.6667	3.3333	0.5057	0.4385
CCC	O4	5.3333	4.0000	0.5996	0.4486
CCC	U2	3.3333	4.0000	0.2547	0.4431
CCC	U4	5.0000	4.6667	0.4769	0.4334
Poseidon	D2	2.6667	3.6667	0.1248	0.1957
Poseidon	D4	3.0000	3.6667	0.2755	0.4532
Poseidon	E	4.0000	4.0000	0.3519	0.4593
Poseidon	O2	4.6667	3.3333	0.4856	0.4185
Poseidon	O4	5.3333	4.0000	0.5996	0.4486
Poseidon	U2	3.3333	4.0000	0.2391	0.4276
Poseidon	U4	5.0000	4.6667	0.4597	0.4161

Table 7: Synthetic (across all metrics) values for ranked and scalar (0-1) approaches. Ranking 1 and Scalar 1 refer to use of a Single calculated (per station) APF value in the calculation (e.g. Tables 3 and 4). Ranking 2 and Scalar 2 refer to use of habitat based APF to produce a combined APF per station (e.g. Tables 5 and 6).

Table 8 uses the data in Table 7 and each value in the each of the response columns (Ranking 1, Ranking 2, Scalar 1 and Scalar 2). This yields a table of ranks that allows comparison of synthetic metrics (e.g. across APF, MLC, SLC).

Group	Station	Ranking 1	Ranking 2	Scalar 1	Scalar 2
CCC	D2	1	2.5	1	1
CCC	D4	2	2.5	3	7
CCC	E	4	5	4	6
CCC	O2	5	1	6	3
CCC	O4	7	5	7	5
CCC	U2	3	5	2	4
CCC	U4	6	7	5	2
Poseidon	D2	1	2.5	1	1
Poseidon	D4	2	2.5	3	6
Poseidon	E	4	5	4	7
Poseidon	O2	5	1	6	3
Poseidon	O4	7	5	7	5
Poseidon	U2	3	5	2	4
Poseidon	U4	6	7	5	2

Table 8: Ranks for all response columns in Table 7. Ranking 1 and Scalar 1 refer to use of a Single calculated (per station) APF value in the calculation (e.g. Tables 3 and 4. Ranking 2 and Scalar 2 refer to use of habitat based APF to produce a combined APF per station (e.g. Tables 5 and 6).

Consideration of the metrics

This analysis has relied on three metrics, APF, MLC and SLC as a basis for assessing the potential entrainment impact for each station. Of the three metrics (APF, MLC and SLC), the most appropriate approach in theory is APF because it reflects risk to entrained species and risk is, ecologically, the most appropriate assessment of impact. Assessment of risk is complicated because loss needs to be expressed in term of entrainment mortality calibrated to population vulnerability. APF can provide species-specific risk but in terms of an overall assessment that is relevant to the array of species entrained, it relies on estimation across multiple species representative of the entrained species assemblage. It is also, by nature of the need to determine population vulnerability, a very data-hungry calculation. At a minimum, it requires data on: (1) species-specific entrainment over a period representative of temporal patterns of larval abundance, (2) species-specific concentration in the source water, (3) species-specific demographic information for entrained individuals (e.g. age structure and length data), (4) oceanographic transport to establish species-specific source water bodies, and (5) information for enough species to be representative for the purpose of statistical evaluation (e.g., to produce a confidence interval for APF that would be representative of all species). If all 5 criteria were available for each proposed intake station, APF would be the clear best choice. In theory, such a study could have been designed for a station assessment, but here we are trying to use historic

data (not always matched in time) for a study where station comparison was not part of the monitoring design. These considerable constraints limit the utility of the APF approach for the question at hand – leading to the use of other metrics: MLC and SLC.

APF, MLC and SLC can all be used individually, but because of limitations of all approaches, as described above, there was consideration of taking a "multiple lines of evidence" (MLE) approach in the hope that there would be more clarity as to station-specific impact. This led to ideas about how to combine APF, MLC and SLC to produce a simple and combined ranking. The two used here (rank based and scalar based) represent ends of a spectrum. The mean rank approach (taking the means of station ranks for all metrics) implicitly assumes that actual difference in a metric between stations is best considered a step rather than a measurable increment. For example, assume there are three stations (A, B and C) with three values for APF (10, 100, 110). These would be ranked in order of lowest to highest impact: 1, 2, 3, even though pairwise differences (AB, AC and BC) are quite different (90, 100, 10). The key advantage for ranks over some other approach is that the units for APF, MLC and SLC are all the same and stations can be ranked from 1-7 for all three metrics.

The other approach used here, the one based on relative scalars, also produces the same units (0-1) for all metrics. Here, however, the differences between stations are maintained in the scalar. The key issue with this approach is the underlying assumption that the range between lowest and highest station for any metric represents a range from low to high impact (this is also true for ranks) rather than, say, a gradient within the low impact range. This assumption is one that we have informed but it is generally a policy decision. Fortunately, results are similar for the two approaches.

Conclusion of independent reviewer

The discussion presented in the previous section aligns with discussion among the groups leading up to this report. Here, I am presenting my personal assessment. First, I do not think that the use of APF is appropriate, given the design-imposed limitations for comparison of stations as discussed above. Second, MLC and SLC are robust to the issues associated (for this study) with APF. Third, MLC and SLC provide different types of information concerning risk, discussed briefly below. Fourth, I do not think that formal inferential statistics are likely to be useful for the comparisons of interest, especially given the use of two metrics and the goal of producing a joint estimate. If there is a need for inferential statistics, the basis should not be the individual metrics but rather the joint MLC/SLC metric. I am providing an example of this below.

MLC is a very simple metric that allows estimation of likely larval loss due to entrainment at each station. Here, lower values unambiguously indicate lower overall larval mortality than higher numbers. It is a metric very sensitive to the most common species. MLC does not provide any way to estimate risk to individual species or across species.

SLC is a metric that addresses the issue of disproportionate contribution of species that are common in samples by standardizing the measurements of each species using Z transformation. This yields a means (across stations) for each species =0 with standard deviation =1. Hence, all species count the same in the SLC assessment.

Both MLC an SLC are indicators of impact and now the question is how to use both to provide a joint calculation of potential impact. Below I take a somewhat different approach than was discussed above. This is based on the assumption that in the absence of any policy guidelines, MLC and SLC should count the same. There should be some reflection on this assumption because it leads to a complicated analytical approach and potentially different answers than analyses based on a single metric.

Assuming that both metrics should be used, I based the approach (and this differs from the joint methods discussed above) on the idea that given equal weighting of metrics, the station with the lowest impact is that one that is the closest to the minimum values (e.g. rank =1 or scalar =0) for both metrics. This might lead one to conclude that this is best represented as the arithmetic mean, but in fact it is not. Instead, it is best represented by the Euclidean mean, which here is simply the Euclidean solution: $A^2+B^2=C^2$**.** This is shown graphically below. Here, the rank for each station for MLC and SLC is plotted in x, y space. In place of the typical rectangular grid, there is a set of arcs that are of distances 1-7 from the origin (0, 0). Dots are stations and, assuming that impact is equally related to MLC and SLC, decreasing impact is toward the origin and increasing impact is further from it. As an example, consider two stations A and B. For MLC and SLC, station A ranks are 3 and 3 (lower ranks are better). B ranks are 1 and 5. The arithmetic means are 3 for both stations. The Euclidean solution for station A = sqrt ($MLC^2 + SLC^2$) = sqrt (9+9) = 4.24 and that for B = sqrt (1 + 25) = 5.09. Using arithmetic means, both stations would be considered to have the same impact whereas using the Euclidean solution station A would be considered less impactful than B. The results for the actual stations using ranks are shown in Figure 1.

Figure 1: Use of Euclidean distances to assess joint metrics of impact. Arcs indicate distance from origin.

Figures 2a and 2b shows the Euclidean values for the joint metrics MLC and SLC for both ranks (EDR; Table 3) and scalar distances (EDS; Table 4) for all stations. Qualitatively these results indicate that for the two metrics assessed, the estimated entrainment impacts ranked from worst to best station:

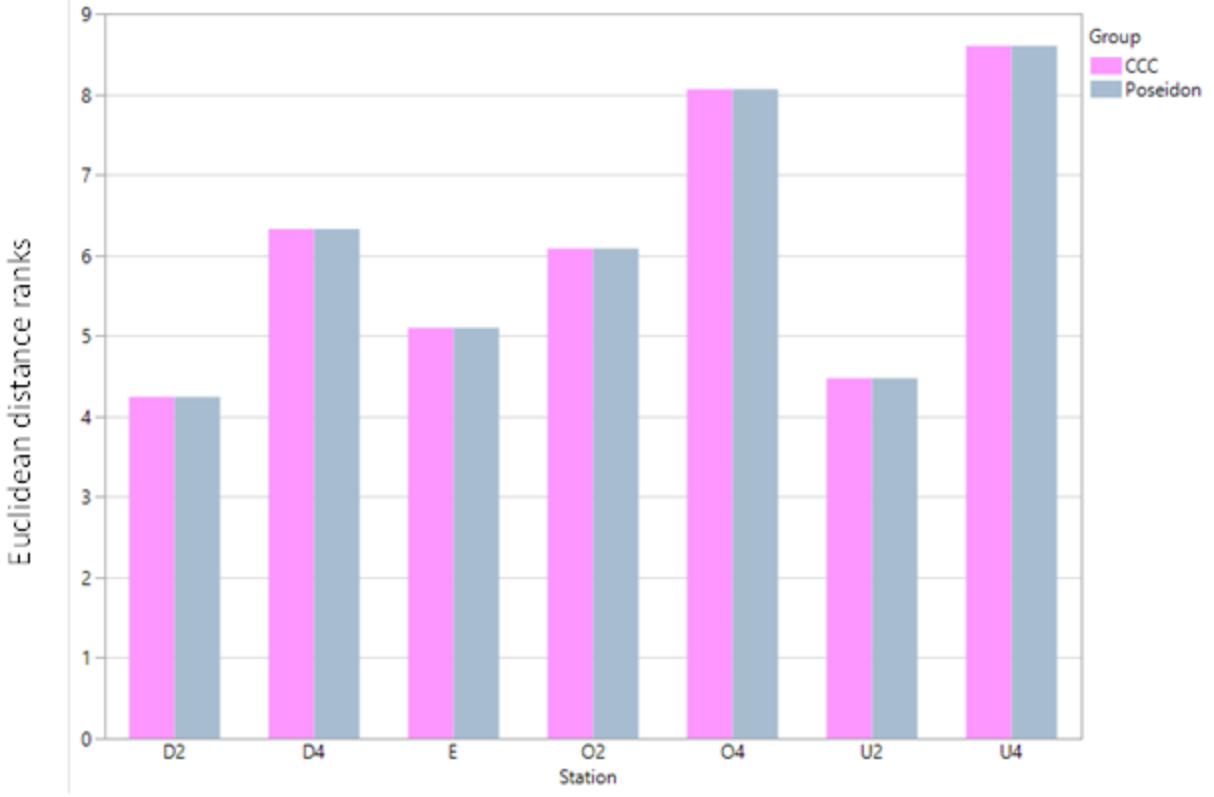
- ranks: U4>O4>D4>O2>E>U2>D2
- scalar: O4>U4>D4>E~O2>D2>U2

Note these rankings are based solely on estimated entrainment effects based on MLC and SLC and do not incorporate the other qualitative or quantitative considerations included in either the Poseidon or CCC reports.

If the use of inferential statistics (e.g. hypothesis testing with confidence intervals) is important, then the statistics have to be based on the synthetic values (e.g. EDR, EDS). The complication of such calculations is not the measure of central tendency (e.g. mean or median). Instead it is modeling the variance structure of values derived from two variables each with their own variance structure. This can be done analytically making assumptions about covariance and the shape of distributions or it can be done using a resampling process. This is what was done here. As a test of the procedure I used only MLC and SLC scalars for each station. These were resampled (bootstrapped) 2500 times for each station for MLC and SLC producing 2500 means for

both for each station. For each of the iterations at each station I then calculated the EDS yielding 2500 estimates of the mean EDS for each station. From these distributions the most supported value (the most commonly found value, which is also the median) and the confidence interval of the median can be directly calculated. Here I used both the 95% and the 50% confidence intervals to give an indication of how sensitive the comparisons are to the critical p-value. These data are presented in Figure 3. For pairwise comparisons, if the confidence interval of a station overlaps with the median of another station, they are not significantly different at the P=0.05 (95% CI) or the P=0.50 (50% CI) level. Note that such analyses are based on confidence intervals that are somewhat arbitrary. I use the word arbitrary because the selection of the confidence interval was done in the absence of consideration of type 2 error (concluding that there is no difference between stations when there actually is one). Also the confidence interval is assumed to be based on 2 tailed considerations. If one was only concerned with identifying if a station was lower than another station the depicted confidence intervals (one tailed) would be 90% (instead of 95%) and 75% (instead of the depicted 50%). Using the 95% confidence interval (or 90% if one tailed) all stations are lower than O4 but not any other station. Using the 50% confidence interval (or 75% if one tailed) there are many more patterns; for example, D2, E and U2 are all lower than D4, O2, O4 and U4. The difference between the results using the two confidence intervals is due to variability within stations being high relative to between stations.

Finally, I want to state that I believe an ETM/APF approach that was designed to compare entrainment impact among proposed intake stations might have produced better separation of results (e.g. APF values) among stations and separation that was clearly based on ecological risk (ETM/APF) rather than proxies for elements of risk (MLC, SLC).



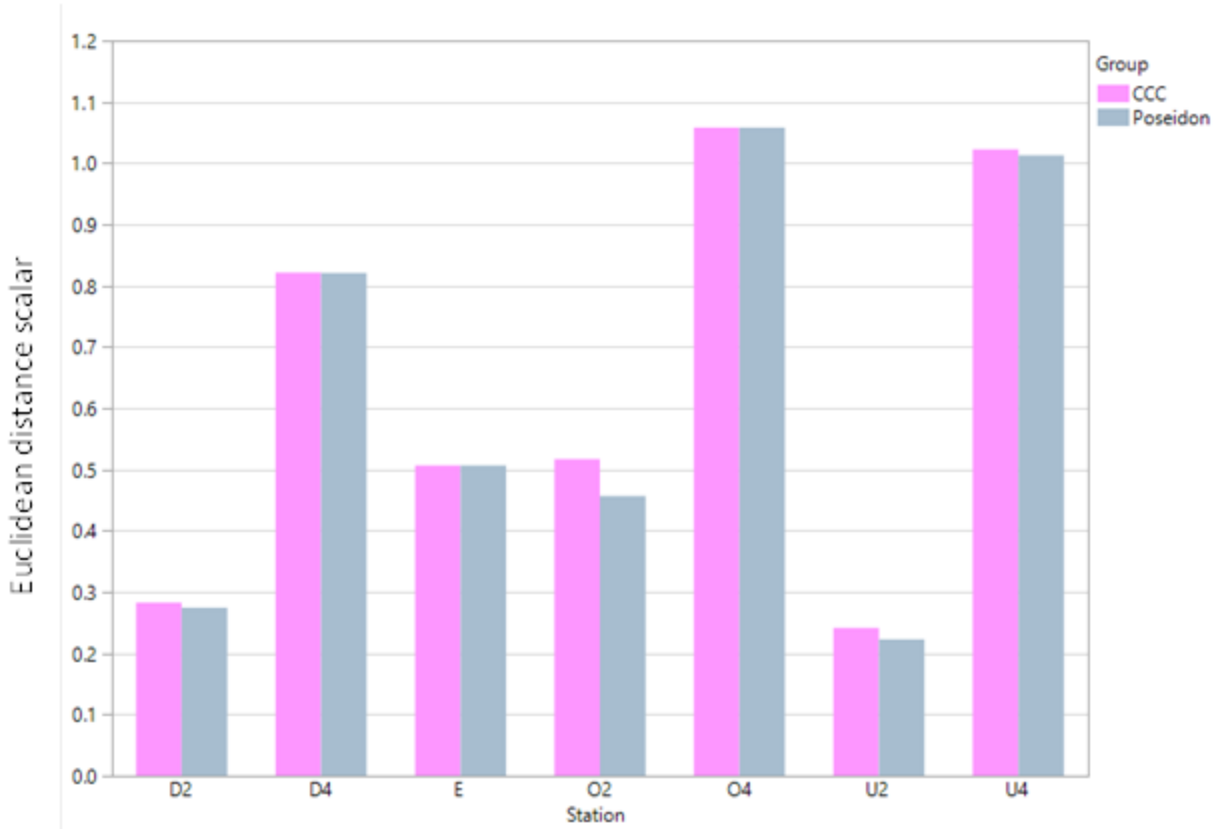


Figure 2: 2a: the relationship between Euclidean distances of ranks (EDR) and station. 2b: the relationship between Euclidean distances of scalar distances (EDS) and station.

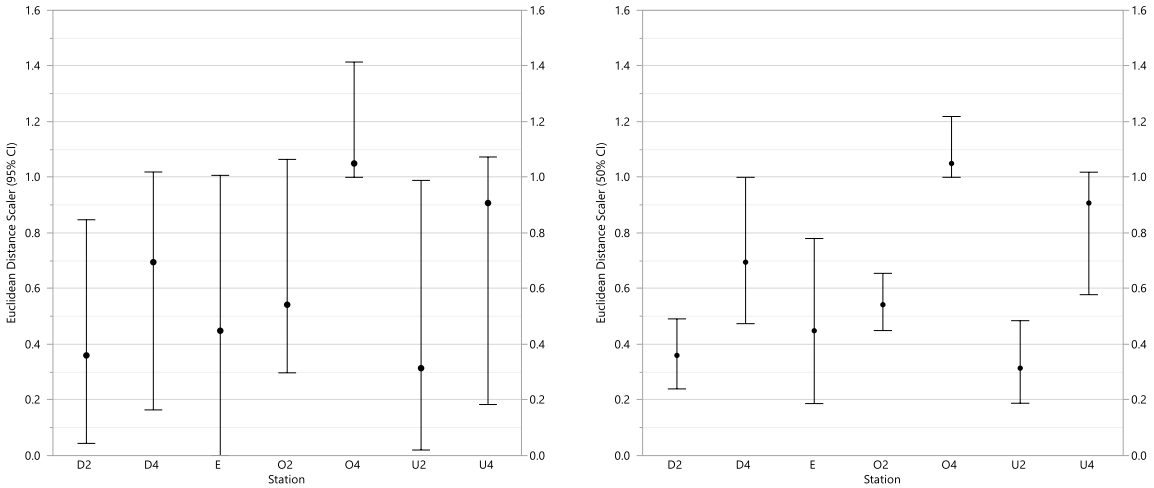


Figure 3: Results of resampling model for the Euclidean Distance Scalar (EDS). Shown are the means +- the 95 percent confidence level of the median (left) and +- 50 percent confidence level of the median (right).

Mitigation APF Estimate for Station E

Poseidon and CCC staff separately estimated APFs for intake-related entrainment at Station E based on: 1) a proposed intake volume of 106 MGD; 2) the same suite of 12 taxa; 3) the same larval concentration data collected in 2003-2004 at each of the six source water stations and Station E; 4) larval durations representing the time period over which larvae are susceptible to entrainment, calculated as the difference between the 1st and 99th length percentiles for larval lengths collected at Station E and converted to days based on the documented relationship between larval length and growth rate for each taxa; 5) ocean current measurements recorded using acoustic doppler current profilers in the study area during two 12-month deployments (1999-2000 and 2007-2008); and 6) the estimated estuarine larval source water concentrations for estuarine taxa collected in Alamitos Bay and Agua Hedionda Lagoon. The calculation methodology was included using the standard ETM for all coastal taxa and a modified ETM for those estuarine taxa entrained at an open coastal site. The ETM and APF calculations for the coastal and estuarine taxa were done separately to allow for separate mitigation scaling for each; however, any scaling will be done later and is not part of my review. Both Poseidon and CCC staff calculated two APFs, one for each ocean current measurement, and then averaged these estimates.

Habitat assignments were based on the agreed-upon source water locations (i.e., estuarine or open coast) for each taxon (CIQ Goby and Diamond Turbot were classified as estuarine while the remaining taxa were classified as open coast). Procedurally, for each of the two habitat groups, the 95% confidence interval was calculated using standard practice for an APF determination, which includes calculating: 1) the mean APF for each habitat group; 2) the standard error across taxa for each habitat group; and 3) the 95% confidence interval, using the MS-Excel NORM.INV function but substituting standard error for standard deviation in the application of this function. The final estimated APF represents the sum of the two habitat groups' 95% confidence interval APFs. Initially, intake entrainment ETM/APF was calculated by Poseidon and CCC staff separately, with those results presented in Table 9 below. The resulting APFs were calculated using an intake volume of 106 MGD as an input to the model. The final APF represents the average of the APFs derived for each ocean current measurement.

Table 9 includes the APFs calculated by Poseidon and CCC staff for intake-related mortality. Differences are likely primarily due to rounding errors. One substantive difference stems from the difference in larval duration values used in calculating ETM for mole crab, *Emerita spp.,* the most abundant species entrained. Poseidon used a value of three days, while CCC staff used a value of five days.

It is important to note that the APF estimates reported for station E in Table 9 are not the same as those shown in Tables 1 and 2. This is because we limited the taxa assessed for the calculations reported in Tables 1 and 2 to those for which there were sufficient data for the calculation of APF at all stations. Using all 12 taxa provides additional data for the calculation of the mean and 95% confidence interval.

Review of the total APF for the proposed project (i.e., intake and diffuser) is not within the scope of my report. However, to calculate a total APF, the intake APF should be added to the discharge

APF. To calculate the discharge APF, the APF for the intake should be proportionally scaled. The discharge scaling factor is calculated based on the volume of water exposed to shearing-related mortality and the intake volume. For example, if the shearing-related mortality volume were 200 MGD, and the intake volume 106 MGD, then the ratio would 200/106 = 1.887. As such, each taxon-specific APF from the intake would be multiplied by 1.887. The discharge scaling factor should be applied to each taxon ***before*** the 95% CI is calculated. After adjusting the taxon-specific APFs, the new 95% APF is calculated. This is the discharge APF. The total APF will then be a sum of the intake and discharge APFs. Please remember that other sources of mortality from construction or operation may occur from the proposed project, which are not discussed in this report.

			Poseidon APF Estimates (ac)			**CCC APF Estimates (ac)**		
Estuarine Taxa	**Pm**	**SWA (acres)**	**1999-00**	**2007-08**	**Mean**	**1999-00**	**2007-08**	**Mean**
CIQ	0.341%	2278.63	7.8	5.7	6.8	7.3	5.4	6.3
Diamond Turbot	0.119%	2278.63	2.7	2.0	2.4	2.6	1.9	2.3
Mean			5.2	3.9	4.6	4.9	3.7	4.3
Std Err			2.5	1.9	2.2	2.3	1.8	2.0
95% CI			9.4	6.9	8.2	8.7	6.6	7.6
Coastal Taxa								
Black Croaker	0.041%	57290.06	23.4	23.5	23.5	23.3	23.3	23.3
California halibut	0.057%	55750.59	31.9	31.9	31.9	31.7	31.7	31.7
combtooth blennies	0.111%	18583.53	20.6	20.6	20.6	20.6	20.6	20.6
Jacksmelt	0.230%	16824.14	38.7	38.7	38.7	38.8	38.8	38.8
mole crab	0.540%	5827.97	31.5	31.6	31.5	50.0	50.1	50.1
Queenfish	0.189%	85330.30	161.5	160.9	161.2	161.1	161.1	161.1
rock crab	0.303%	87419.57	265.0	265.8	265.4	265.7	265.8	265.7
Spotfin Croaker	0.097%	14075.10	13.6	13.6	13.6	13.7	13.7	13.7
Northern Anchovy	0.297%	100614.98	298.5	297.8	298.2	298.8	298.9	298.8
White Croaker	0.148%	68726.08	101.4	101.4	101.4	101.1	101.2	101.1
Mean			98.6	98.6	98.6	100.5	100.5	100.5
Std Err			33.9	33.8	33.8	33.5	33.6	33.5
95% CI			154.3	154.2	154.3	155.6	155.7	155.7
Total Est + Coastal APF			163.7	161.2	162.4	164.4	162.3	163.3

Table 9. Area of production foregone (APF) estimates for each ocean current speed and the mean APF across both ocean current speeds derived by Poseidon and the CCC. Taxa are split into two habitat groups: estuarine taxa and coastal taxa.