California Marine Life Protection Act Initiative
Draft Methods Used to Evaluate Marine Protected Area Proposals in the MLPA South Coast Study Region
Appendix 3 – Summary of Life History Parameters Used in Bioeconomic Models and Their Sources

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Life-history parameters for each modeled species were obtained by searching the published scientific literature, stock assessments, and the 2000 Pacific States Marine Fisheries Commission report prepared by G. Cailliet et al. At present this appendix describes parameters obtained and used by the UC Davis model; there is an ongoing collaboration between the UC Davis and UC Santa Barbara groups to double-check and revise (as necessary) these estimates. Some parameters are still tentative pending contact with various experts who may possess unpublished data. Furthermore, the modeling groups will circulate this document among appropriate scientific experts, including those on the MLPA Master Plan Science Advisory Team (SAT), to confirm the accuracy of these estimates. Therefore some values may be revised as the MLPA South Coast Project progresses.

Parameters Used

Movement

Because management with MPAs involves creating differences in conditions (i.e., fishing mortality rate) over space, the effects of individual movement have a critical effect on sustainability and yield. Two kinds of biological movement are important, dispersal during the larval stage and swimming movement during juvenile and adult stages.

Juvenile/Adult Swimming

Most of the species that will be protected and sustained by the MLPA either have very little adult movement, or move within a specified home range. For some of these the sizes of the home ranges have been estimated using acoustic tags. This type of movement can be considered well known for species that have been studied in this way. In general, we report home range size in terms of diameter, which facilitates implementation in a one-dimensional model. We note that there is greater confidence in estimates derived from acoustic tagging studies than from simple tag-recapture studies.

Larval Dispersal

The models use estimates of larval dispersal derived from the ROMS-based Lagrangian particle-tracking model developed by UCLA and UCSB. In this approach, each species is characterized by pelagic larval duration (PLD) and spawning season.

Life History

Both reproduction and yield depend on the sizes of individuals, which depends on how fast they grow through life. Here we present size versus age in terms of the dependence of length on age in the most commonly used form, a von Bertalanffy growth function. The parameter L_∞

represents the mean length for very old individuals, the parameter k represents the growth rate at young ages, and the parameter t_0 essentially describes the length of an individual at age 0. We also present size versus age in terms of weight, which is calculated from size via an allometric relationship, $W = aL^b$. The values of a and b are given for each species.

Reproduction depends on the age of maturity and fecundity. Fecundity, f, the number of eggs produced by a female of a certain age or size in a year, is commonly assumed to be proportional to weight, but is sometimes also calculated from an allometric (or other) relationship with length.

Mortality consists of two components, fishing mortality and natural mortality. Here we present instantaneous mortality rates.

The size ranges that are available to be caught by the fishery are either specified by regulation or estimated from fishery or other data.

Compensation Ratio / Critical Replacement Threshold

Species persistence, and thus all model results, depend heavily on the shape of the settler-recruit relationship. This relationship describes the per-capita mortality of settlers as a function of settler density; settlers surviving this initial bout of post-settlement mortality are considered ‘recruits’ into the benthic population. This curve is generally described in terms of the slope at the origin; it is assumed that the curve has a Beverton-Holt functional form and that the asymptotic maximum density can be made nondimensional by scaling all model results to the baseline unfished case.

The settler-recruit curve is analogous to the stock-recruit curves utilized in non-spatial fishery models. The slope at the origin of the stock-recruit curve can be described as a non-dimensional compensation ratio, which is the ratio of per-capita settler survival at very low densities (settlers = 0) to per-capita survival of settlers at the highest possible density in the unfished state. The inverse of this number (1/CR) is also referred to as the critical replacement threshold (CRT), because it is the fraction of lifetime egg production (FLEP) below which the population is not persistent. That is, if CR = 5, CRT = 1/5 = 0.2, and if fishing reduces lifetime egg production below 20% of its unfished maximum, the population will collapse. Estimates of the CR are generally difficult to obtain except for species that have been fished below the CRT and therefore collapsed. As a consequence we know the CR for only a few fished species. Dorn (2002) estimated a CR of approximately 3 for several collapsed species of north Pacific rockfishes. This CR is likely to be a conservative estimate, especially since some southern California species are likely to be somewhat more resilient than those rockfish species. Therefore, both models use a reasonable but nonetheless conservative estimate of CR = 4 (CRT = 0.25) for the settler-recruit curves for each species.

Although the choice of CR will affect the model results, by far the largest effect will be on the sensitivity of the population to fishing. This effect on sensitivity to fishing should largely be accounted for by the methods used to choose fishing effort outside of reserves. Because fishing effort in each of the future fishing scenarios is chosen as some constant fraction of CRT (or MSY, in the case of the UCSB model), the potential for the choice of CR to affect model outcomes should be much reduced.

Species Notes

At this time we are evaluating the effects of MPA designs on 10 species. In this text and the tables that follow, we provide both reported estimates of each parameter and, for those parameters with different estimates or a range of values, we indicate the value we have chosen to use in our models. Unless otherwise noted, all distances are in km, all organisms lengths are in cm, and all masses are in kg.

Kelp bass (Paralabrax clathratus)*

Our estimate of home range size is based on acoustic telemetry studies (Lowe et al. 2003). The estimate of < 1 km actually encompasses some rare longer-distance movements, as most fish use home ranges smaller than this estimate.
Fishing for kelp bass is exclusively recreational.

Barred sand bass (Paralabrax nebulifer)*

Most life history information available from Cailliet. Unpublished movement data may be available from C. Lowe and are being sought. We assume that PLD and spawning are similar to kelp bass.

California scorpionfish (Scorpaena guttata)*

Growth and other life history data in Love et al. (1987, Fishery Bulletin) and the Cailliet database. PLD reported by Reed & Carr (1993). Existing tag-recapture results suggest (erroneously) high movement, this information is currently being revised using unpublished data from D. Hanan.

California Sheephead (Semicossyphus pulcher)*

Our estimate of home range size is based on acoustic telemetry studies (Topping et al. 2005, 2006). The same authors also suggests that sheephead prefer ecotone habitat that spans both sand and rocky reef.

Sheephead are sequential, protogynous hermaphrodites in which females change sex to become territorial haremic males. Recreational spearfishing primarily targets the large terminal phase males, commerical live-fish fishery targets the smaller females, and recreational hook-and-line fishing targets both sexes (Hamilton et al. 2007). There is evidence that historical and contemporary fishing patterns have produced geographical differences in sheephead life history traits (growth rates, maturation time, timing of sex change) across the Southern California Bight (Hamilton et al. 2007, unpublished data).

Kelp rockfish (Sebastes atrovirens)*

Most data available in Cailliet database.

Ocean Whitefish (Caulolatilus princeps)

Our estimate of home range size is based on acoustic telemetry studies (Bellquist et al. 2008). Fishing for ocean whitefish is primarily recreational, although there may be some bycatch in the live fish fishery (CDFG 2003). The status of the fishery is essentially unknown because it is widely assumed that larval fish settle in Mexico and eventually migrate to California waters as adults (CDFG 2003). However, coastal benthic trawl surveys in 1969-1999 found that whitefish recruitment does occur in California waters, primarily in warmer years (Bellquist et al. 2008).

Opaleye (Girella nigricans)

No home range data are available for non-tidepool individuals; still checking citations in Davis (2001). PLD is 2-4 months (Waples 1987 Evolution).
Life history info is available from Bredvik's CSUN masters thesis (von Bertalanffy curve, etc).

Black perch

Cailliet database has life history parameters.
No larval stage.

Kellet's whelk (Kelletia kelletii)

Unpublished data may be available from D. Zacherl and C. White.

Red sea urchin (Strongylocentrotus franciscanus)*

There are several references for the duration of the larval stage of red sear urchin (?). Red sea urchins move very little after settlement (less than 10 m).

Growth and mortality rates have been estimated from size distributions collected along the coast of northern California (Morgan, et al. 2000). The parameters of a von Bertalanffy relationship are $k=0.28\ y^{-1}$ and $L_\infty = 11.25$ cm y^{-1}. The parameters of an allometric relationship between weight (gm) and test diameter (mm) are the constant = , and the exponent = (Kalvass??). The size at maturity is 6.0 cm (ref) and the allometric dependence of fecundity on length has a constant equal to 5.47×10^{-6} and an exponent equal to 3.45 (ref).

Table 1: Kelp bass *(Paralabrax clathratus)* parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	3-4 weeks		Carr 1994, Cordes & Allen 1997
Spawning season	Spawn in late spring to early fall, peaking in summer, but may spawn multiple times per season		Lavenberg et al 1986, Oda et al 1993
Mean larval dispersal	Not found		
Home range diameter	<1 km		Young 1963, Lowe et al 2003, California's Living Marine Resources
Length-at-age (cm TL) von Bertalanffy equation: $L(t)=L_\infty\left(1-\exp\left(-k\left(t-t_0\right)\right)\right)$			Love et al 1996
L_∞	69.8		
k	0.06		
t_0	-3.5		
Weight-at-length () $W = áL^{â}$	I believe it's inTL and oz, but could be mmTL, g		Young 1963
á	0.00376		
â	3.27		
Maximum age	>34 yr		California's Living Marine Resources
Age at maturity	3 yr		Love et al 1996
Batch Fecundity-at-length (# of eggs, mm TL)	*logBF = 3.02logTL – 3.13*		DeMartini 1987
Natural mortality rate	0.25		Young 1963
Available to fishery	12 in TL		CDFG Regulations

Table 2: California sheephead *(Scorpaena guttata)* parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	34 -78 days		Leet et al 2001
Spawning season	larval availability peaks July to Oct, females spawn approximately 86 times per year		Cowen 1985, DeMartini et al 1994
Mean larval dispersal	Not found		
Home range diameter	1 km		Topping et al 2005, Topping et al 2006
Length-at-age (cm) von Bertalanffy equation: $L(t)=L_\infty\left(1-\exp\left(-k\left(t-t_0\right)\right)\right)$			Alonzo et al 2004 SA
L_∞	83.86		
k	0.068		
t_0			
Weight-at-length (cm/kg) $W = áL^{â}$			Alonzo et al 2004 SA (converted from DeMartini et al 1994)
á	0.000026935		
â	2.857		

Parameter	Value Reported	Value Used	Source
Maximum age	15-53	30?	Limbaugh 1955, Fitch 1974, Warner 1975, Cowen 1985, Cowen 1990
Age at maturity	4		Warner 1975, Alonzo et al 2004 SA
Sex change to male	7-8 yrs, 30cm SL, 36.7cm FL		Warner 1975; Cowen 1990, Alonzo et al 2004 SA
Fecundity-at-weight	average of 15,000 eggs per kilogram of body weight		DeMartini et al 1994
Natural mortality rate	0.2 – 0.35		Warner 1975, Cowen 1990, Alonzo et al. 2004 SA
Available to fishery	12 in (rec), 13 in (comm)		CDFG regulations

Table 3: Ocean Whitefish (*Caulolatilus princeps*) parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	Not found		
Spawning season	late autumn to early spring / most gonads spent by april / found ripe females in all months except Aug		Elorduy-Garay & Ramirez-Luna 1994, Dooley 1978
Mean larval dispersal	Not found		
Home range diameter	1 km		Bellquist et al 2008
Length-at-age (mm TL)			
von Bertalanffy equation: $L(t) = L_\infty\left(1 - \exp\left(-k\left(t - t_0\right)\right)\right)$			Cooksey 1980
L_∞	772.92		
k	-0.231038		
t_0	-0.016		
Weight-at-length (g)			
$W = \acute{a}L^{\hat{a}}$			Cooksey 1980
$\acute{a}$	0.000002		
$\hat{a}$	3.15		
Maximum age	13 yrs		Love 1996
Age at maturity	3-4 yrs ("probably")		Cooksey 1980
Fecundity-at-length $F = \tilde{a}L^{ç}$	Not found		
$\tilde{a}$			
ç			
Natural mortality rate	Not found		
Available to fishery	1.5 yrs for CPFVs, majority caught by sport fishermen are 250-400mm TL		DFG Marine Status report 2003*, Cooksey 1980

* www.dfg.ca.gov/marine/status/report2003/oceanwhitefish.pdf

Table 4: Black perch (*Embiotoca jacksoni*) parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	0		Love 1996
Spawning season	April - June, OR throughout the year w/ no peak season		Schmitt & Holbrook 1984, Isaacson & Isaacson 1966
Mean larval dispersal	< 1 km		Love 1996
Home range diameter	< 1 km		Hixon 1979, Hixon 1981
Length-at-age (mm SL) von Bertalanffy equation: $L(t) = L_{\infty}(1 - \exp(-k(t - t_0)))$			Froeschke et al 2007
L_{∞}	217.9		
k	0.3562		
t_0	-1.648		
Weight-at-length (g) $W = \acute{a}L^{\hat{a}}$			Froeschke et al 2007
á	0:000085		
â	2.8636		
Maximum age	4-10 yrs	>9 yrs (Love 1996)	Holbrook & Schmitt 1984, Schmitt & Holbrook 1985, Holbrook & Schmitt 1995, Love 1996
Age at maturity	1-2 yrs	likely age 1 in socal	Love 1996, Froeschke et al 2007
Fecundity-at-length (mm SL) $F = \tilde{a}L$ - ç			Froeschke et al 2007
ã	0.145		
ç	14.9		
Natural mortality rate	*Not found*		
Available to fishery	*Not found*		

Table 5: Kelp rockfish (*Sebastes atrovirens*) parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	2 months	2 months	Standish et al 2008
Spawning season	March-June	March-June	Love et al 2002
Mean larval dispersal	*Not found*		
Home range diameter	0-10 km	5 km	Miller & Geibel 1973, Lea et al 1999, D. Hanan personal communication
Length-at-age (cm SL) von Bertalanffy equation: $L(t) = L_{\infty}(1 - \exp(-k(t - t_0)))$			Love et al 2002
L_{∞}	28.5		
k	0.29		
t_0	-0.03		
Weight-at-length (cm TL, g) $W = \acute{a}L^{\hat{a}}$			Love et al 2002
á	0.0239		
â	2.862		

Parameter	Value Reported	Value Used	Source
Maximum age	>25 yrs		Love et al 2002
Age at maturity	4-6 yrs		Love et al 2002
Fecundity	Produce 10,000-275,000 eggs		Love et al 2002
Natural mortality rate	*Not found*		
Available to fishery	*Not found*		

Table 6: California scorpionfish (*Scorpaena guttata*) parameters and values reported

Parameter	Value Reported	Value Used	Source
Pelagic larval duration	30 days		Carr & Reed 1993
Spawning season	April-August, peaking in July		Love et al 1987, Love 1996, Leet et al 2001
Mean larval dispersal	*Not found*		
Home range diameter	1-200km, with mean 12 km and SD 33 km		Hartmann 1987, Love et al 1987, D. Hanan personal communication
Length-at-age (cm TL) von Bertalanffy equation: $L(t)=L_\infty(1-\exp(-k(t-t_0)))$			Love et al 1987
L_∞	44.3		
k	0.13		
t_0	-1.9		
Weight-at-length (cm TL, g) $W = \acute{a}L^{\hat{a}}$			Love et al 1987
$\acute{a}$	0.0196		
$\hat{a}$	3.0102		
Maximum age	21 yrs		Love et al 1987, Love 1996, Leet et al 2001
Age at maturity	2 yrs		Love et al 1987
Fecundity (cm TL, g)	$f = \begin{cases} 0 & TL \le 13 \\ (0.0012TL - 0.0155)W_{TL} & 13 < TL < 30 \\ 0.2W_{TL} & TL \ge 30 \end{cases}$		Maunder et al 2005 SA
Natural mortality rate	0.25 assumed in stock assessment		Maunder et al 2005 SA
Available to fishery	8 in (comm.), 10 in (rec)		Maunder et al 2005 SA