abundance shows that, though catch rate was relatively high from 2010 to 2015 (Van Diggelen 2017), paralarval abundance was anomalously high during the same time period (Wells et al. 2017). Furthermore, Van Noord and Dorval (2017) conclude that the highest impact on paralarval (and therefore adult) market squid abundance appeared to be environmental factors, with their study focusing on El Niño and La Niña conditions specifically.

In summary, although abundance relative to sustainable levels is unknown, the combination of a non-high vulnerability to overfishing and multiple data-poor approaches, with distinct data sources suggesting no reason to conclude the stock is overfished, allows for a score of "low" concern.

Justification:

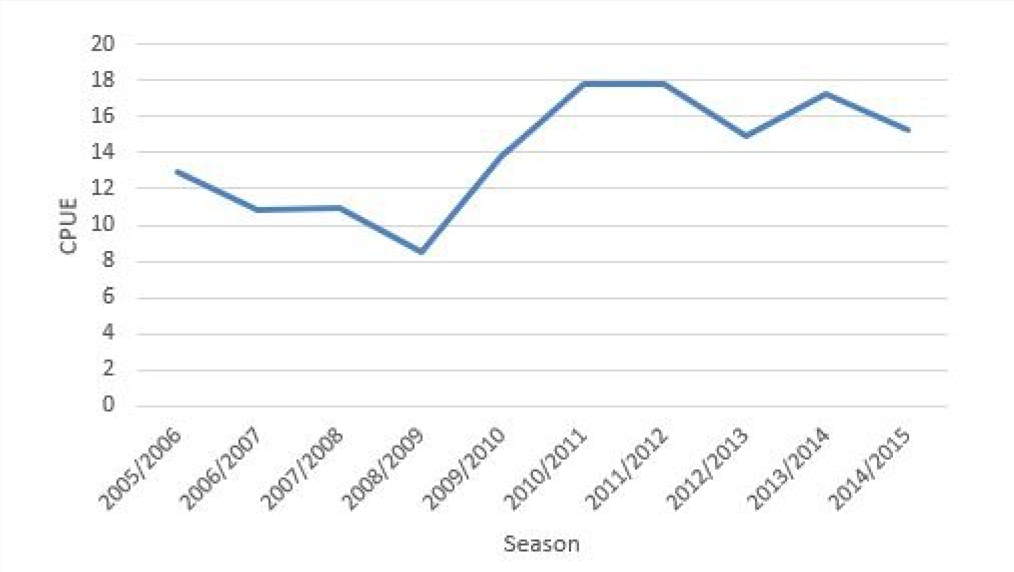

Figure 4 Market squid catch per unit effort from commercial data (landings/set) for the seasons 2005-2006 to 2014/2015 (Van Diggelen, 2017).

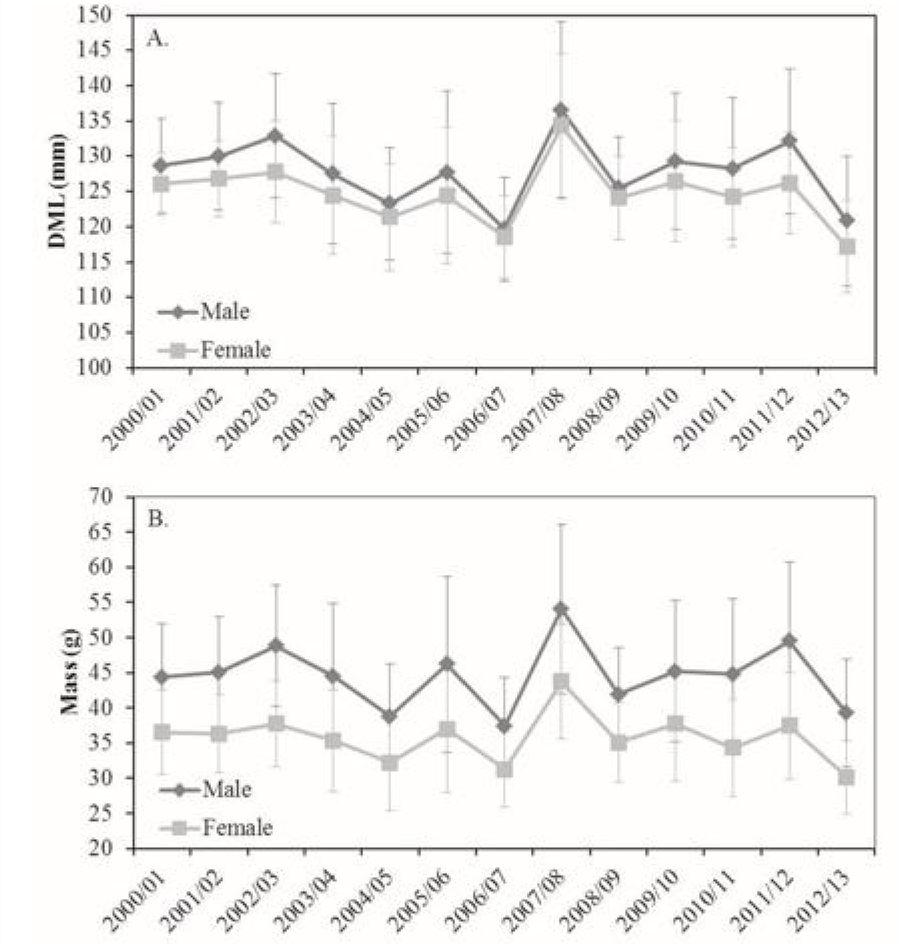

Figure 5 Mean (±SD) dorsal mantle length (DML; A) and mass (B) for male and female California market squid across all regions by commercial fishing season (Figure from Protasio et al., 2014).

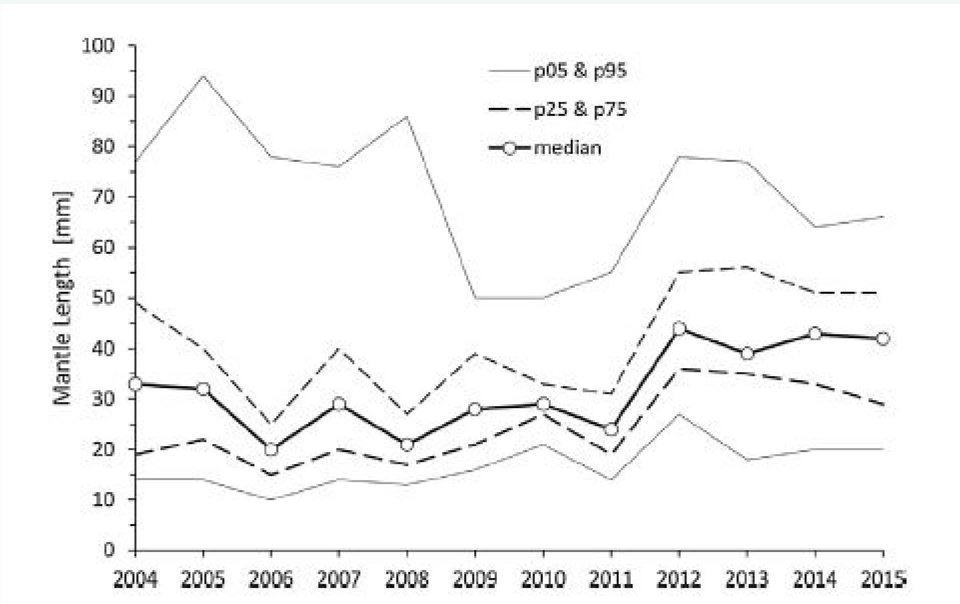

Figure 6 Median mantle length of market squid taken in the midwater trawl survey from 2004-2015. The 5th (p05), 25th (p25), 50th (median), 75th (p75), and 95th (p95) percentiles of survey catches are depicted for each year (Figure from Ralston et al., 2018).

Market squid are short-lived, semelparous animals, meaning they live less than one year and die soon after spawning. As a result, there is no generational overlap and the population size reflects only the previous generation's spawning success and the new generation's survivorship (Dorval et al. 2013) (Zeidberg 2013). The commercial harvest from year to year is inconsistent, and numerous studies indicate paralarval abundance is highly linked to environmental factors (Vojkovich 1998) (Zeidberg et al. 2006) (Koslow and Allen 2011) (Van Noord and Dorval 2017).

The best measure currently for squid population trends is the catch data provided by the fishery (PFMC 2014). Established in 1863, California's market squid fishery did not expand much until the late 1980s. Seasonal landings of market squid began and continued to increase from 1986 until 2003 to 2008, when landings fell from a high of 118,902 MT to a low of 38,099 MT (CDFW 2016a) (Figure 1). Landings started to rebound after 2009, and in 2013 the market squid fishery was California's largest fishery, with landings estimated at 104,404 MT (PFMC 2014), a value that was maintained in 2014 with landings over 104,084 MT. In 2015–2016 the population again declined to 2003 to 2008 levels (CDFW 2016a) (Figure 1). Although fishing occurs predominately on spawning aggregations in shallow water, squid have been documented at greater depths (Zeidberg 2013) (Van Noord and Dorval 2017). Behavior can change during El Niño periods, driving the squid to deeper water, resulting in low stock biomass in the shallower areas typically fished, and rendering the stock unavailable to the fishery (Van Noord and Dorval. 2017). Therefore, it is unclear if trends in catch data reflect availability to the fishery or overall stock size (NMFS 2012) (CDFW 2005). Landings are also affected by squid size available to the fishery and market demand.

Environmental factors play a large role in influencing market squid biomass, and can be the cause of large declines in commercial landings in some years. Large inter-annual population fluctuations are believed to largely occur in response to environmental factors (Vojkovich 1998) (Zeidberg et al. 2006) (Koslow and Allen 2011) (Van Noord and Dorval 2017), and market squid abundance appears to be strongly related to El Niño Southern Oscillation (ENSO) cycles. During extreme El Niño events (e.g., 1982–83, 1997–98, 2006), both squid landings and catch per unit effort declined (Zeidberg et al. 2004) (Porzio 2012), although in La Niña years they have historically been high (Marinovic 2007) (Marinovic 2003). The available evidence suggests that dramatic fluctuations in landings are more likely due to changes in abundance driven by environmental factors, rather than shifts in availability to the fishery (Reiss et al. 2004) or as the result of pressures exerted by the fishery (Van Noord and Dorval 2017).

Productivity-Susceptibility Analysis:

Scoring Guidelines
1.) Productivity score (P) = average of the productivity attribute scores (p1, p2, p3, p4 (finfish only), p5 (finfish only), p6, p7, and p8 (invertebrates only))
2.) Susceptibility score (S) = product of the susceptibility attribute scores (s1, s2, s3, s4), rescaled as follows: $S = [(s1 * s2 * s3 * s4) - 1/ 40] + 1$.
3.) Vulnerability score (V) = the Euclidean distance of P and S using the following formula: $V = \sqrt{(P^2 + S)^2}$

Figure 7

Using the scores presented in the table below, it was determined that market squid have an overall productivity score (P) of 1.66 and an overall susceptibility score (S) of 2.33, giving market squid a vulnerability score (V) of 2.862, a medium level of vulnerability. For details on the PSA scoring and approach, please see the Seafood Watch Standard for Fisheries (v3.1) on our website at http://www.seafoodwatch.org/seafood-recommendations/our-standards (permalink http://www.montereybayaquarium.org/-

/m/C3EE8C68DA2A47B18A64BE6DBA72F76F.pdf).

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	6 months *(Zeidberg, 2013)*	1 (<1 yr)
Average maximum age	6-9 months (Zeidberg, 2013)	1 (<10 yrs)
Fecundity	3,000 eggs (Macewicz et al., 2004)	2 (100-20,000 eggs per yr)
Reproductive strategy	Demersal Egg Layer (Zeidberg, 2013)	2 (Demeral egg layer or brooder)
Trophic level	3.05 (Caddy and Sharp, 1986)	2 (2.75-3.25)
Density dependence (invertebrates only)	No density or compensatory dynamics demonstrated of likely	2 (No depensatory or compensatory dynamics demonstrated or likely)
Productivity		1.66

Susceptibility Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Areal overlap (Considers all fisheries)	Unknown, default score used	3 (>30% of the species concentration is fished, considering all fisheries. Default score if unknown)
Vertical overlap (Considers all fisheries)	Target Species	3 (High degree of overlap between fishing depths and depth range of species. Default score for target species, as well as any air-breathing animal, or when unknown)
Selectivity of fishery (Specific to fishery under assessment)	High risk does not apply (see Key Information above)	2 (Species is targeted, or is incidentally encountered AND is not likely to escape the gear, BUT conditions under 'high risk' do not apply. Default score when conditions under 'high risk' do not apply)
Post-capture mortality (Specific to fishery under assessment)	Retained species	3 (Retained species, or majority dead when released, or unknown. Default score for retained species or unknown)
Susceptibility		2.86

Figure 8

Factor 1.2 - Fishing Mortality

CALIFORNIA/EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Moderate Concern

For market squid, egg escapement is currently used as a proxy for MSY, with escapement limits set at 0.30 (PFMC 2014). Dorval et al. (2013) estimated a range of 0.08 to 0.75 (and in most quarters higher than 0.3) when they broke down the most heavily fished areas on the California coastline into three separate regions. This suggests that proportional egg escapement was generally higher than 30% in most fishing seasons during that time period (Dorval et al. 2013). The data used in that study were from 1999 to 2006, now more than a decade old. Work is currently ongoing to improve understanding of the fishery's impacts on the population, including improvement in the timely estimation of critical parameters of the egg escapement model ("the mantle condition index") (McDaniel 2015) and extension of the Dorval et al. (2013) time series to 2014, and the development of a long-term index of paralarval abundance (Van Noord and Dorval 2017) (Wells et al. 2017) (Ralston et al. 2018) (PFMC 2017). Based on the information currently available, however, it is unclear whether the egg escapement model is a good proxy for MSY, or whether egg escapement in recent years has been above the goal. For these reasons, fishing mortality relative to a sustainable level is considered unknown, and a score of "moderate" concern is applied.

Justification:

For market squid, the Overfishing Limit (OFL) and Allowable Biological Catch (ABC) are both set at the fishing mortality that results in a threshold level of egg escapement of at least 30% (the proxy for MSY) (http://www.pcouncil.org/wp-content/uploads/I2c_SUP_SSC_NOV2010BB.pdf). At the time these thresholds were set, managers considered the state measures in place (weekend closures, area closures, harvest cap) enough of a buffer to not worry about setting the ABC lower than the OFL (pers. comm., J. Lindsey, 29 March 2017).

Recent efforts to better estimate market squid biomass and egg escapement are improving researchers' abilities to determine abundance and fishery impact. One study in particular broke down the California coastline into the three major fishing regions, each of which encompass multiple known spawning grounds (Dorval et al. 2013) (Figure 7). This model demonstrated a certain level of variability in spawning biomass based on fishing region, producing a maximum peak abundance of spawning stock in two of the three regions studied ranging from 215,000 to 254,000 MT in a single quarter (Figure 6). The third region studied was often several orders of magnitude lower. However, authors noted that, given the inherent annual and inter-annual variability in the market squid population, real time sampling would be needed to make any conclusive statements about long term trends in the fluctuations of biomass in a healthy market squid population. Such sampling would be both exceptionally time consuming and costly. For these reasons there are no biological reference points based on biomass for this fishery. CDFW uses the "egg escapement method" as a measure of fishing mortality (CDFW 2005). This approach relies on mantle length and gonad measurements. The method assumes the weight of a typical egg and uses that to compute the number of eggs in a sampled female, and then compares that value to the potential fecundity at the given mantle length in order to compute the realized fecundity. A mean is calculated for the stock based on the samples taken in given areas at given times, resulting in an egg escapement value for the stock. The target reference used under this approach is the ratio of realized- to maximum-potential fecundity and is set at an egg escapement of 0.30. However, given that different fishing levels can produce a 30% proportional egg escapement (pers. comm., E. Dorval, 11 October 2016), it is difficult to directly convert this into a relative F_{MSY}.

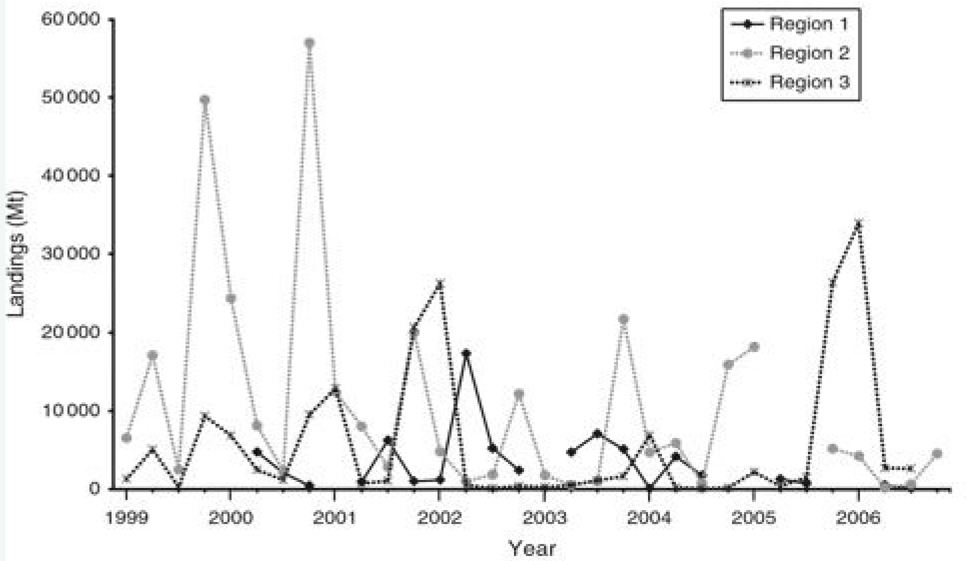

Figure 9 Landings (Mt) of market squid in California by Region and quarter from 1999 to 2006 (Figure from Dorval et al., 2013).

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤=3.2=Yellow or Moderate Concern*
- *Score ≤=2.2=Red or High Concern*

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding Principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Only the lowest scoring main species is/are listed in the table and text in this Criterion 2 section; a full list and assessment of the main species can be found in Appendix A.

CALIFORNIA MARKET SQUID - CALIFORNIA/EASTERN CENTRAL PACIFIC - PURSE SEINES - UNITED STATES OF AMERICA					
Subscore:	**5.000**	**Discard Rate:**	**1.00**	**C2 Rate:**	**5.000**

Species	Abundance	Fishing Mortality	Subscore
No other main species caught			

There is currently no observer program in place for the squid fishery. A pilot observer program from 2004 to 2008 found no species that regularly consist of >5% of the catch in this fishery (see tables in the discards section below). Pacific sardine, Chinook salmon, and marine mammals are discussed below, but none are assessed any further herein (see p. 16 in the Seafood Watch Wild Capture Standard V 3.2 for an explanation of the thresholds for inclusion in an assessment).

- Pacific sardine are incidentally caught and landed, and though the volume landed is typically low relative to the directed fishery, the incidental catch has increased as a percentage of total fishing mortality due to zero landings from directed fisheries in the US (closed since July 2015) and Canada (since 2012). From 2017 landings data, less than 0.1% of market squid landings contained NSP sardine, accounting for <4 MT total of NSP sardine. Other sources of fishing mortality appear to have been much higher that year (117 MT landed in the live bait fishery, and nearly 8000 MT landed in the Ensenada sardine fishery) (pers. comm., K. Lynn, CDFW; K. Hill, NOAA (PFMC 2017c)).

- Chinook salmon is caught and is a species of concern, but the occurrences of this species as bycatch are reported to be very infrequent, and in most years were reported in less than 1% of all observed loads (PFMC 2014), levels deemed by managers to be low enough to not be of concern (pers. comm., J. Lindsay, 3 October 2016).

- Some marine mammals, specifically sea lions, seals, and common dolphins as well as gulls are considered occasional bycatch (PFMC 2011). The mammals are not generally caught, but rather seen jumping in and out of the net, and managers do not consider the bycatch of marine mammals a concern for this fishery (pers. comm., J. Lindsay, 3 October 2016). Furthermore, NOAA classifies the California market squid fishery as a Category III fishery, meaning that there is "a remote of or no known incidental mortality and serious injury of marine mammals"(NOAA 2018). The effects of so-called "seal bombs" being used to protect nets and otherwise deter marine mammals in the market squid fishery are unknown. The noise from detonations, which can number up to tens of thousands in a single site a month, could potentially affect the behaviour of marine mammals, especially cetaceans such as blue and fin whales, Cuvier's beaked whales, and Pacific-white sided and Risso's dolphins. Risso's dolphins could be especially vulnerable to the noise source, as they tend to be less opportunistic in their prey selection than other mammals and so may be more dependent on squid abundance. Research on this topic is in the early stages, with nothing on actual impacts published or conclusive at this time (Meyer-Löbbecke 2017) (Meyer-Löbbecke 2016) (pers. comm., S. Baumann-Pickering, UCSD 2018).

2.4 - Discards + Bait / Landings

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

< 100%

Discards are minimal (Table 2) and no bait is used in this fishery.

Justification:

Target species - Squid					
Species	Target Catch	Incidental Catch	Bycatch Returned		
			Alive	Dead	Unknown
Squid	1274 mt		28 mt	350 lbs	2 mt
Anchovy		100 lbs	120 lbs		
Jack Mackerel		2 mt	18 lbs	2 lbs	
Pacific Mackerel		20 mt	20 mt	180 lbs	1 lb
Sardine		12 mt	13 mt	1077 lbs	3 lbs
Spanish Mackerel		20 lbs			
Bat Ray			53		1
Bat Star			1		
Blue Shark			2		
Common Mola			1		
Pelagic Stingray			60		
Pacific Butterfish		19			1
Sunstar		30	4		
Squid Eggs					505 lbs
Lobster			3		
Brittle Star				3000	
Unid. Batfish				2 lbs	
Unid. Crab		1	1		93
Unid. Croaker		3	2	16 lbs	
Unid. Flatfish		1	1	6	2
Unid. Jellyfish		4			
Unid. Mackerel		2 lbs	102 lbs		
Unid. Octopus		1			
Unid. Rockfish		1	1	4	
Unid. Ray			4		1
Unid. Sanddab		4	3		4
Unid. Seastar		1			
Unid. Seaslug					21
Unid. Scorpionfish		1			
Unid. Surfperch				3	
Unid. Skate		3		1	
Unid. Smelt		49			
Unid. Stingray		9	17		
Unid. Shark					1
Thresher Shark		1			
CA Sea Lion			98		
Harbor Seal			3		
Common Dolphin				1	
Unid. Gull			16	1	

Figure 11 Preliminary catch summary from vessels targeting market squid from NMFS-SWR coastal pelagic species pilot observer program, 2004-2008. Table from (PFMC 2011)

(PFMC 2011).

Common name	2008 Metric Tons	2009 Metric Tons	2010 Metric Tons	2011 Metric Tons	2012 Metric Tons	2013 Metric Tons
Market Squid	38,100	93,107	130,851	121,513	97,461	104,355
Anchovy, northern	34	10	2	6	1	5
Bonito, Pacific	2	1	0	0	0	0
Mackerel, jack	46	73	16	74	70	19
Mackerel, Pacific	199	240	79	330	128	92
Sardine, Pacific	497	328	94	279	190	113

Figure 12 Annual reported squid landings and incidental catch reported on landing receipts with greater than fifty percent market squid (by tonnage per landing) from 2008 – 2013 for round haul purse seiners. Table adapted from (PMFC, 2014) and (NMFS, 2016).

(PFMC 2014) (NMFS 2016).

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2 = Red or High Concern*

Rating is Critical if Management Strategy and Implementation is Critical.

GUIDING PRINCIPLE

- The fishery is managed to sustain the long-term productivity of all impacted species.

Criterion 3 Summary

Fishery	Management Strategy	Bycatch Strategy	Research and Monitoring	Enforcement	Stakeholder Inclusion	Score
Fishery 1: California / Eastern Central Pacific | Purse seines | United States of America	Moderately Effective	Highly Effective	Moderately Effective	Moderately Effective	Highly Effective	Yellow (3.000)

Criterion 3 Assessment

Factor 3.1 - Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Moderately Effective

The market squid fishery is managed by the California Department of Fish and Wildlife under the Market Squid Fishery Management Plan. Measures include weekend closure dates (noon Friday to noon Sunday), which provide for uninterrupted spawning; a restricted access program with provisions for initial entry into the fishery, permit types, permit fees and permit transferability; an annual (1 April to 31 March) catch limit of 118,000 short tons (107,047 MT) (Porzio 2012) (CDFW 2005), and numerous spatial closures. The CDFW is currently in the process of revising the Marine Life Management Master Plan, which will influence the way all California fisheries are managed (CDFW 2018). In addition, the CDFW is working on an "Enhanced Status Report" which can act as a tool to inform any actions (pers. comm., CDFW 2018). Whether any of this work will lead to actual changes in the management of the market squid fishery is yet to be seen.

The fishery is also monitored under the Coastal Pelagic Species Fishery Management Plan at the Pacific Fishery Management Council. Although no biomass-based reference points have been developed due to the life history and plasticity of the species, numerous data-poor approaches suggest little reason for concern over the population being overfished (see Criterion 1). Fishing mortality-based reference points have been set at a threshold of two consecutive years of exceeding the egg escapement goal of at least 30% (see Criterion 1), at which point it could be considered for more active management. It is not clear how the PFMC determines whether escapement goals have been met in a timely manner; however, since the latest analysis was by Dorval et al., based on data from 1999 to 2006 (Dorval, Crone, and J.D. McDaniel. 2013). The fishery lacks the more robust reference points and stock assessments used for similar fisheries around the world (e.g., Japanese flying squid in Japan (Yamashita, Norio, et al. 2013) (Hideaki, Kidokoro. et al. 2013) (Japanese Fisheries Agency 2015) (Japanese Fisheries Agency 2015); longfin squid in the US—biomass reference points only (Hendrickson, L.C. 2017)). The strategy also has a weakness in terms of ratcheting down permitted fishing mortality during years of low abundance, and there is no minimum biomass set below which fishing should not occur. For these reasons, management strategy and implementation is deemed "moderately effective."

Justification:

Both the annual catch limit and the egg escapement limits were formulated partially in consideration of the fishing mortality of the previous decade, during which time there were multiple years with landings >100,000 tons without any decline in landings during the following years, indicating this level of catch is sustainable (CDFW 2005). Catch limits based on historical catch are supported by guidance from NOAA fisheries, which states that “in data-poor situations such as the market squid fishery, a proxy may be used for MSY, and that it is reasonable to use recent average catch from a period when there is no qualitative or quantitative evidence of declining abundance” (PFMC 2014). A proxy was therefore used to determine the MSY because there was not adequate data to make a mathematical MSY determination. The average of the landings obtained in the ten, five, and three years before the report was used as a proxy for MSY. This was then used to determine the annual catch limit (118,000 short tons), though the least conservative (highest volume) catch limit was ultimately selected (CDF&G 2005, Table 3.2), a limit based on historically high landings in the three immediately preceding seasons (1999 to 2002). The ability of the fishery to support landings of greater than 100,000 tons in the 1999/2000 fishing season and then sustain landings of the same magnitude over the next two seasons was thought to demonstrate the population could withstand this level of fishing (CDFW 2005). Dorval et al. (2013) agreed with this sentiment, indicating that because the fishery captures mostly adult squid (95% of landings) that have likely already released much of their eggs before capture combined with the weekend, Channel Island, and MPA closures give the opportunity for a high proportion of egg escapement to offset the negative effects of the fishery on the stock (Dorval, Crone, and J.D. McDaniel. 2013)

Large-scale spatial closures within state-designated ecological reserves, such as the Channel Islands and areas protected under the Marine Life Protection Act (MLPA), provide additional areas where uninterrupted spawning can occur (Porzio 2012). At least 14.6% of available market squid spawning grounds in Southern

California are within no-take marine protected areas, but the relative contribution of these MPAs to market squid spawning success and recruitment is not known (Van Diggelen 2017).

Permits are required for any directed take of market squid (CDFW 2013). The catch limit does not take into consideration market squid caught for use as bait, since this is believed to be a relatively low percentage of catch for this species. Furthermore, there is the question of the presence of market squid egg capsules in a small percentage of the purse seines. Despite the suggestion that the origin of these egg capsules could be explained by aging the embryos within the egg capsules to determine whether or not they were laid after the squid within the net had been captured, there is no evidence this has thus far been implemented (PFMC 2014). This is more fully addressed in Criteria 4.1a.

Factor 3.2 - Bycatch Strategy

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Highly Effective

Based on the catch reported via landing receipts with greater than 50% market squid, this fishery has very limited bycatch, and with no species besides the target species making up >5% of the catch, no species of concern regularly caught, and limits in place for the incidental catch of sardine, bycatch strategy is deemed "highly effective."

Factor 3.3 - Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Moderately Effective

The short lifespan and rapid turnover of the California market squid make it challenging to establish an accurate, up-to-date stock assessment. Though egg escapement data are calculated based on gonad weight of captured squid (PFMC 2017) and some scientific studies have been conducted on the impact of the fishery on the market squid population, the large time and monetary commitment required to collect samples for these studies limit them to a frequency too low to enable implementation of real-time management strategies. Research has been conducted that suggests exploitation may be at a sustainable level, but it is currently based on fisheries data only (Dorval, Crone, and J.D. McDaniel. 2013)(Protasio 2014), and in the case of Dorval et al., on data that is more than ten years old. There is no public evidence that egg escapement is calculated in reasonable timeframes. Studies examining the use of paralarval abundance as an indicator of future CPUE have demonstrated this as an effective and accurate tool (see Criterion 1.1). If used in management, this should aid greatly in the ability to estimate each year's exploitable biomass through annual pre-fishing season surveys, as is strongly recommended for cephalopod fisheries by researchers, e.g. (Rodhouse et al. 2014) and is conducted for some other squid fisheries (see C3.1).

Bycatch is thought not to be a problem, based on a pilot observer program in place from 2004 to 2008. However, it would be prudent to confirm that this is still the case given that the study was conducted a decade ago and there have been anecdotal reports of Risso's dolphins (a species not observed caught during the pilot program) caught in squid nets in 2018 (KION 2018). In addition, current efforts to determine the impacts of deterrents such as seal bombs on mammals associated with the squid fishery, especially Risso's dolphins, should be continued (see Criterion 2).

The score for this factor is driven by a rating of "moderately effective" for the research and monitoring of the fishery's impacts on the squid population.

Justification:

As mentioned above there are no estimates of biomass currently available for this species. Though there are some data on the stock status in regards to long term trends, at this time "there is no reliable measure of annual recruitment success beyond information obtained from the fishery" (PFMC 2014); nonetheless, studies on paralarval abundance have given a valuable insight into the effects of environmental fluctuations on the market squid population. Koslow and Allen, (2011) found that market squid paralarval abundance in the Southern California bight is significantly correlated with near-surface temperature, nutrient and chlorophyll concentrations, the El Niño-Southern Oscillation Index (ENSO), and to a lesser extent with the Pacific Decadal Oscillation (PDO) (Koslow and Allen 2011). A more recent study has concluded that, not only does abundance of market squid at all life stages decline during El Niño, but adult squid behavior changes in a way that reduces catchability (Van Noord and Dorval 2017). ENSO and PDO indices could thus be used as a rough fishery independent indicator of market squid stock size. Monitoring of the ENSO and PDO indices could be used to predict an upcoming drop in the market squid stock size and facilitate adaptive, real-time management of the market squid resource (Koslow and Allen 2011), but this has not yet been attempted. Numerous studies have been conducted on the reproductive habits of market squid (Macewicz 2004) (Forsythe, Kangas, and Hanlon. 2004) (Zeidberg, et al. 2011)(Zeidberg, et al. 2004), a particularly important factor in informing the use of egg escapement as a proxy for MSY. Observations using ROVs during peak squid mating season revealed that squid mating and egg laying predominantly occur at night on sandy bottoms and within a narrow temperature range (10 to 14.4 °C) (Zeidberg, et al. 2011).

Studies have also been used to determine that the fishery has not had an impact on the size at maturity or sex ratio (Protasio 2014). However, environmental factors such as the ENSO can have an effect on body size, resulting in smaller squid with slower growth rates during El Niño compared to squid during La Niña (Jackson and Domeier 2003) (Reiss et al. 2004). The standard method of recording body size in this species is through measurement of the dorsal mantle length (DML) and body mass. Although both DML and mass frequently fluctuate from season to season, there has been no indication of a substantial decrease in either category over the past 13 years (Protasio 2014). A best-case model of spawning stock status and showed spawning stock levels implied the current catch limit is quite conservative (Dorval, Crone, and J.D. McDaniel. 2013). Dorval and his colleagues also looked at the maturity of squid caught by the fishery and found that immature squid accounted for less than 5% of the catch in most of areas they studied, leading to the conclusion that the spatial dynamics in the overall fishery do not appear to noticeably influence spawning and reproduction of the overall squid population. However, the study acknowledged that, given the brevity of the fishing seasons (3 to 4 months) and the species' rapid turnover of generations, it is difficult to collect and process enough samples for this method to provide data for real time management.

A study conducted by Zeidberg et al. (2011) suggested that, when taking the average market squid lifespan (6 to 10 months) into consideration, many squid caught by the commercial fishery must have been spawned during a season that has not traditionally supported the squid fishery. The authors suggest that surveys of egg beds in the seasons that have not traditionally supported market squid fisheries would allow for better understanding of migration and spawning patterns and could provide management with valuable information. Many suggest incidences of bottom contact with the purse seines are minimal; the official stance of the Pacific

Fishery Management Council is that the exact extent to which the purse seines contact the sea floor and contribute to the mortality of market squid egg capsules is currently unknown (PFMC 2014). In this document it is indicated that examining the egg capsules found within the purse seine and aging the embryos would be a reliable method to determine if the eggs were taken from the sea floor or laid by already captured females within the net; this practice does not appear to have been implemented at this time. Seafloor contact associated with the use of purse seine nets in shallow water and the subsequent mortality of squid eggs have been poorly studied, but acoustic techniques used to estimate egg beds on shallow substrates could help assess this damage (Foote et al. 2006). It has been demonstrated that acoustic surveys could serve as important management tools by efficiently mapping the locations of spawning grounds used, which are subject to frequent change from one spawning season to the next (Young, et al. 2011) (Foote, et al. 2006). Performing reconnaissance mapping early in each fishing season could help to determine how many spawning areas are protected by MPAs already in place and designate seasonally adaptive no-take spawning zones if needed. Estimating biomass of both reproductive output and the population could be used to help develop stock assessments (Young, et al. 2011). However, a dynamic, spatially based management system would be both cost and time prohibitive, and may not incur any additional benefits over the current static system, which allows undisturbed areas to establish complex and resilient ecosystems overtime (pers. comm., Van Noord 2018).

Factor 3.4 - Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Moderately Effective

CDFW enforces existing regulations through the use of mandatory logbooks and port-side samplers that collect data on landings and bycatch. At this time there is no evidence of substantial illegal fishing. Monitoring of the catch allows managers to close the fishery before the catch limit of 118,000 short tons (107,047 MT) is reached e.g., (CFDW 2010)(CDFW2011). However, since the catch limit was implemented with the completion of the Market Squid Fishery Management Plan in 2005, the catch limit has been exceeded twice, in 2010 and 2011 (see Figure B in the Introduction and repeated below), which suggests monitoring and enforcement may not be enough to control fishing effort in years of high squid abundance. Enforcement is therefore considered "moderately" effective for this fishery.

Justification:

The CDFW is the governing body that manages the California market squid fishery. There are several mechanisms in place to work to ensure sustainable fishing practices within this fishery (CDFW 2005). Permitting is well enforced, and there is a restricted access program in place for this fishery, which has a capacity goal of 55 market squid vessel permits, 18 market squid brail permits, and 34 light boat permits. Permits are not required to catch market squid for use as live bait, because this is believed to be a relatively low percentage of catch for this species. Also important to the scoring of this factor is the enforced use of port sampling and logbooks from the CDFW to track data on landings and bycatch. In addition to the pilot observer program initiated by NMFS from 2004 to 2008, dock-side sampling for this species is currently conducted by CDFW in the counties where the majority of squid landings occur. This includes Monterey, Santa Barbara, Ventura, and Los Angeles, with the primary goal of “monitoring changes in the biological characteristics of market squid in the fishery and to characterize California’s commercial market squid fishery.” Efforts have also been made to obtain 12 samples of market squid per month from each main port complex and to get visual species composition of sample loads in areas that have been landing market squid only in the more recent years. These areas include San Francisco, Half Moon Bay, Bodega Bay, and Eureka (pers. comm., C. Protasio, 31 August 2016).

Landings are frequently sampled to look for the presence of market squid egg capsules to ensure compliance with the set egg escapement limit. An examination of fishery data collected from Monterey, Santa Barbara and Los Alamitos from 1999 to 2006 determined that "proportional egg escapement was generally higher than 0.30 in most quarters," and "spatial dynamics in the overall fishery do not appear to noticeably influence reproductive processes of the overall market squid population" (Dorval, Crone, and J.D. McDaniel. 2013). From 2006 to 2010, an average of 9.2% of sampled landings contained market squid egg capsules. In 2015, market squid egg cases were identified in only 3.5% of observed landings, but it is unknown how many of those egg capsules were taken from the bottom or exuded by mature female squid while they were in the net (PFMC 2017).

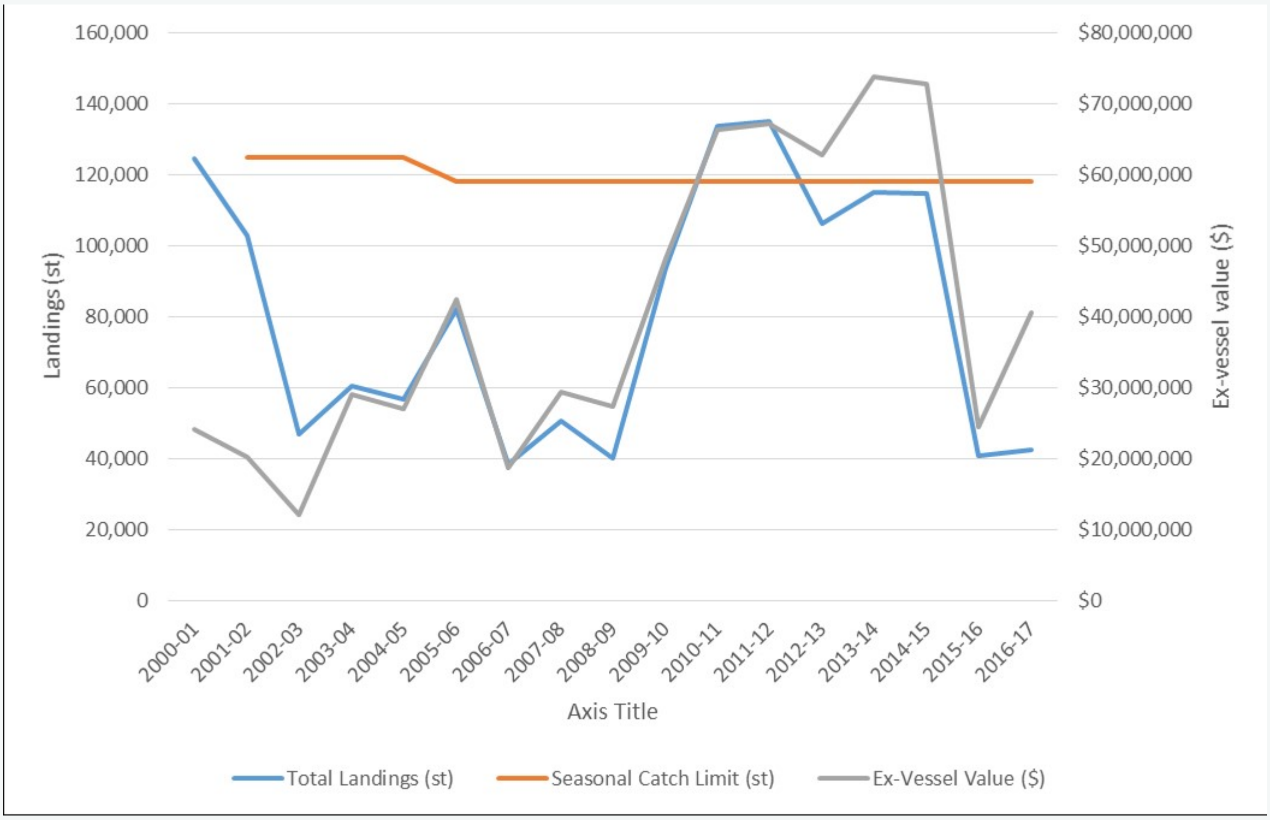

Figure 13 Commercial landings (short tons) and ex-vessel value ($) of market squid in California from 2000-2017. Red line is catch limit; this was exceeded in the 2010-2011 and 2011-2012 seasons. Data from CDFW 2018.

Factor 3.5 - Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Highly Effective

Many stakeholders were involved in the creation of the MSFMP in 2004. Both fishing and conservation interests put forth their desired annual catch limit figures, and a compromise was reached. Surveys are posted on the DF&W website encouraging feedback from commercial fishermen prior to any potential change in regulations, but it is unclear how much influence stakeholders have in any implemented regulation changes. However, the process is transparent. Given that there is no evidence that stakeholders have not been included in management decisions, this category is ranked "highly effective."

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2=Red or High Concern*

GUIDING PRINCIPLES

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

Region / Method	Gear Type and Substrate	Mitigation of Gear Impacts	EBFM	Score
California / Eastern Central Pacific / Purse seines / United States of America	3	0	Moderate Concern	Yellow (3.000)

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*

- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management

Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*
- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

3

The purse seine fishery for market squid occurs in the water column over sandy and muddy substrate (CDFW 2005), and there is some interaction with the benthos. Use of brail gear, a large dip net that can be used with the assistance of hydraulics (CDFW 2005), accounts for a small percentage of the total catch of market squid and has not been shown to have any negative interaction with the benthos. Because this fishery frequently uses purse seines that contact the bottom, this fishery scores 3 out of 5 regarding the physical impact of the fishing gear on the habitat/substrate.

Justification:

The California market squid fishery mainly fishes using purse seine nets and surface pumps (CDFW 2005). Seine nets are generally not known known to inflict habitat damage as long as they do not contact the seafloor. However, this is not the case in the market squid fishery: there is evidence that market squid seine nets do interact with the benthos. Logbooks report that this occurs more often in the northern fishery than in the southern fishery (PFMC 2011). The frequency of such interactions with the benthos is unknown. Evidence of interactions with the benthos comes from bycatch records, which include many species of bottom-dwelling fishes, invertebrates, and mature (>2 weeks old) market squid egg capsules (PFMC 2011). However, the evidence does suggest these interactions are likely to be minimal. Bycatch of bottom-dwelling fish and egg capsules is low, indicating only occasional contact at most. Furthermore, because the fishery occurs primarily over sandy and not rocky bottoms, even with occasional contact damage to the benthos is minimal.

When seine nets drag across the bottom they may be as destructive to the benthos as bottom trawls (Chuenpagdee et al. 2003). However, "purse seines used for squid typically do not hang as deep as purse seines used for other species, so contact with the bottom is reduced" (CDFW 2005). One concern associated with purse seine nets contacting the bottom in sandy habitats is disruption of the market squid's complex mating and egg-laying behaviors, as well as dislodging egg capsules from their attachments to the sandy substrate (Young et al. 2011). Bycatch of squid egg capsules is a potential concern brought up in relation to management of the fishery (CDFW 2005) (PFMC 2014). Because market squid remain in the vicinity of egg capsules during spawning and deposit new egg capsules at the bases of capsules already attached to the substrate (Zeidberg et al. 2011), they can be difficult to target effectively without imperiling eggs, even with the use of lights to draw squid closer to the water's surface. Though the frequency of observations of egg capsules in the nets is relatively low (6.7% in 2013), the fishery's estimate of MSY is based on the number of eggs that escape mortality. Thus, unintentional capture of successfully deposited eggs could cause estimates of survivorship to be inaccurately high and could potentially result in overfishing. However, given that the small percentage of eggs captured in the purse seines is unlikely to have a major impact on fishing mortality at this time, this occurrence is more important as an indicator of potential interaction with the seafloor.

The current trends do seem to indicate that the majority of the egg capsules observed within the nets are likely laid by females that have already been captured within the net, not as a result of direct contact with the sea floor. However, examining the capsules in purse seine nets and aging them to determine if they were laid within the net or if they were laid earlier and caught as bycatch (a practice not currently done) would resolve any dispute on the issue. Fishing nets in the northern fishery have the potential to contact the bottom more frequently than in the southern fishery (PFMC 2011); yet, interestingly, this trend may not be reflected in the frequency of market squid egg capsule bycatch, which has been shown to decrease in frequency in the more northern ports (Table 3). This indicates that contact with the sea floor, though still a possible occurrence, may not explain the presence of egg capsules in the nets.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

0

To reduce the adverse effects caused to seabird populations, managers have closed the waters of the Gulf of the Farallones National Marine Sanctuary to market squid fishing boats using attracting lights. Although several state MPAs protect market squid spawning grounds, there are no regulations specific to the fishery to reduce the incidence of bottom contact by purse seine nets. No points are awarded for mitigation here because it is not clear that areas closed to squid fishing account for at least 20% of representative habitats, and there are no gear modifications designed to reduce seafloor impact.

Justification:

When the California Fish and Game Commission adopted the Market Squid FMP regulations in 2004, it was decided that specific areas for harvest replenishment would not be designated for market squid. This decision was largely due to market squid having a large geographic range (Baja California north to Alaska) in relation to the small to moderate spatial scale of the fishery, meaning that an abundance of areas are unfished for squid (CDFW 2005). However, a network of state marine reserves (SMRs) around Point Conception and at the Channel Islands, including San Nicolas, Santa Barbara, Anacapa, Santa Cruz, Santa Rosa, and San MigueI Islands provide as much as 20 percent of squid spawning grounds as no-take areas in which commercial fishermen are not allowed to fish for market squid. The statewide coastal network of marine managed areas now encompass more than 16% of the California coast, not including special restrictions in San Francisco Bay (CDFW 2016). As part of the MLPA process several no-take state marine reserves have also been established in the vicinity of the northern market squid fishery, including Point Lobos SMR, Asilomar SMR, Lover's Point SMR, Ano Nuevo SMCA, Farallon Islands special closures, and new SMRs in northern California. Although not managed specifically for market squid, these areas effectively provide general habitat closure areas that protect spawning habitat, function as forage reserves, offer protection against bycatch and fishery interactions, and provide areas of uninterrupted spawning for market squid (CDFW 2005). It is estimated that south coast MPAs alone protect a minimum of 14.6% of market squid spawning grounds (Van Diggelen 2017). Large-scale spatial closures within state designated ecological reserves, such as the Channel Islands and areas protected under the Marine Life Protection Act (MLPA), also provide additional areas where uninterrupted spawning can occur (Porzio 2012). Furthermore, the maximum depth of squid purse seiners is likely to be shallower than the maximum depth at which squid spawn. Squid purse seine nets used by vessels in the San Pedro fleet of Southern California had a maximum depth of around 82 m (Lutz and Pendleton 2001), and observations from satellites indicate fishermen rarely deploy nets in water deeper than 100 m (Maxwell 2004). Market squid eggs are typically found between 20 to 70 m, but can be found as deep as 800 m (PFMC 1998). Paralarvae studies by Van Noord also found evidence of paralarvae at offshore banks in 120 m depth off the Channel Islands during El Niño conditions. However, it is unknown whether the closed areas cover 20% of representative habitats (and inaccessible areas are not included in this calculation).

Restrictions on gear focus on the lights used to attract market squid toward the surface. In response to a documented increase in seabird nest abandonment and chick predation, attracting lights are limited to 30,000 watts and must be shielded above the horizontal line of sight (CDFW 2005). Collectively, CDFW believes these measures reduce the potential for overfishing and help to ensure long-term resource conservation and sustainability (Porzio 2012).

In addition, management has prohibited using attracting lights when squid fishing in all waters of the Gulf of the Farallones National Marine Sanctuary (CDFW 2005). These measures were implemented primarily to reduce potential negative effects on nesting seabirds, marine mammals, and important commercial and sport fishes. Additionally, the nature of purse seine gear makes it possible to sort larger non-CPS from the catch with the use of grates, and to release larger fish before pumping or brailing by lowering a section of the cork-line or by using a dip net (PFMC 2011). However, management has not implemented any measures to minimize interactions with benthic habitats and ecosystems nor to reduce the capture of non-target species and market squid egg capsules. Though these effects seem to be minimal, a precautionary management strategy could be implemented by setting net depth limits so that nets do not reach the seafloor.

Factor 4.3 - Ecosystem-Based Fisheries Management

CALIFORNIA / EASTERN CENTRAL PACIFIC, PURSE SEINES, UNITED STATES OF AMERICA

Moderate Concern

Market squid is a key forage species in the California Current ecosystem (though squid are not considered forage species for the purposes of applying the Lenfest Taskforce on Forage Fish guidelines (LenFest 2012). The market squid fishery is managed through a Fisheries Management Plan meant to implement the requirements of the Marine Life Management Act (California's main piece of legislation governing commercial fisheries). The MLMA requires that managers consider ecosystem impacts of a fishery, namely the conservation of not only the exploited species, but the other species that depend on that resource, and the MSFMP contains the goal of providing adequate forage for dependent species (CDFW 2005). According to the MSFMP, this goal is implemented through management measures that reserve a portion of the biomass as forage for all dependent species using such tools as fishery control rules and harvest replenishment areas (CDFW 2005). Example measures include an annual catch limit and weekend closure dates (noon Friday to noon Sunday), which provide for uninterrupted spawning. Though there is a potential for negative impacts on the ecosystem as a result of removal of market squid, the catch limits currently imposed by the fishery limit the take to levels that are unlikely to compete with the natural variability of the market squid population (pers. comm., Van Noord 2018). However, there also remains no cutoff below which fishing should cease, a policy that could ensure forage in years of low abundance. The statewide catch limit may also mask localized declines in biomass that could reduce the availability of forage in some areas.

In addition, the MLMA's sister legislation, the Marine Life Protection Act, has led to a network of MPAs along the California coast that provide some protection of spawning grounds and maintenance of forage and undisturbed nesting/resting sites for some seabird and marine mammal colonies. Furthermore, recent studies have indicated that market squid availability as a forage species actually increased from 2004 to 2014, while most other forage species declined (McClatchie et al. 2016).

Since there are policies in place to protect the ecosystem role of squid, and there are some measures in place that may be effective in implementing those policies, but their effectiveness is uncertain and detrimental food web impacts are possible, this factor is scored a "moderate" concern.

Justification:

Due to apparently high abundance and rapid turnover, market squid are presumed to play a key role in the transfer of production from plankton to higher trophic levels within the California Current Large Marine Ecosystem (CCLME) (Zeidberg 2013). The only ecosystem concern explicitly addressed by current market squid management is the negative effect on nesting seabirds of vessels using light to attract squid. Management has placed restrictions on attracting lights and has closed the waters of the Gulf of the Farallones National Marine Sanctuary to the use of attracting lights as discussed above (CDFW 2005).

There is concern that removing market squid could cause substantial localized changes in the food web (Morejohn 1978)(Jackson and Domeier 2003). Market squid is a common food source for numerous species in the California Current. In Monterey Bay alone, 19 species of fish feed on market squid, including Pacific bonito, halibut, tuna, and all of the depleted, threatened, and endangered salmon stocks along the West Coast (Morejohn 1978) (CDFW 2005) (Brodeur et al.). Market squid are fed on by predators at each life stage. Such predators include black-spot goby, curlfin turbot, sanddabs, salmon, rockfish, blue sharks, shortfin mako sharks, thresher sharks, croakers, midshipman, rays, lingcod, and cabezon (Zeidberg 2013) (Preti et al. 2012). Squid are also consumed by many marine mammals such as the California sea lion, elephant seal, Alaskan fur seal, Dall's porpoise, harbor porpoise, white sided dolphins, pacific striped dolphins, Risso's dolphins, and otters. Many seabirds also eat squid; common murre, cormorant, gulls, kittiwake, loons, auklet, fulmar, and shearwaters have all been known to consume squid (Zeidberg 2013). That said, in all of these instances market squid are simply one component of the diet, and there are no species that seem to rely entirely on market squid. Furthermore, a recent study using data obtained from the Southwest Fisheries Science Center's Rockfish Recruitment and Ecosystem Assessment Survey found that, although the abundance of other forage fish such as sardine and anchovies decreased in abundance from 2004 to 2014, market squid actually increased in abundance (McClatchie et al. 2016). This study also found that the caloric density of the California market squid is much lower than these other forage fish, making it a much less desirable dietary component. This would indicate that the fishery is not having a large impact on the food web as a whole.

Regardless of the low caloric density, predators in the Monterey Bay with market squid as their first or second-ranked prey item according to their index of relative importance (IRI) include speckled sanddab, curlfin turbot, lingcod, arctic loon, sooty shearwater, short-tailed shearwater, pink-footed shearwater, California gull, black-legged kittiwake, rhinocerus auklet, common murre, northern fur seal, California sea lion, harbor porpoise, and Pacific striped dolphin (Morejohn 1978). For many of these animals, importance of squid in the diet is seasonal. For example, the common murre feeds on squid more heavily during the winter and California sea lions eat squid predominantly in the fall and winter. The commercial fishery typically operates at its peak during the summer in Monterey Bay and the winter in Southern California (Zeidberg 2013).

The only known predator of the market squid that is a species of concern as defined by Seafood Watch (overfished, endangered, or threatened) is Chinook salmon. Fishbase has given this species a high to very high vulnerability rating (Fishbase 2016). There is some disagreement on the importance of market squid in the diet of the Chinook salmon, and these differences seem to be primarily spatially driven. For example, Brodeur et al. (2007) examined the diet of multiple juvenile salmon species across multiple regions and determined juvenile market squid (which are not targeted by the fishery) were a significant food source to Chinook salmon found off the coast of California only, which made up a small subsect of the regions studied (salmon in waters north of California did not utilize juvenile market squid as a significant food source) (Brodeur et al.). When Thayer et al. (2014) examined the diet of salmon along the central California current system over a 50 year period, they argued that the diet of Chinook salmon varies seasonally, with squid appearing to be most important during the spring, a time during which the commercial fishery is commonly active. Brodeur et al. (2007) and Thayer et al. (2014) agree that compared to 1955, the abundance of squid in the salmon's spring diet was reduced from the 1980s through the 2000s by 6 to 7%. However, another study focusing on the Northern California current system during summers of 2000 and 2002 did not list market squid as an important prey item (Miller and Brodeur 2007). Thus, location appears to play a large role in the importance of market squid in the Chinook salmon diet, with the importance being much greater in central California. However, it is unclear if the fishery is impacting abundance of squid as a food item for Chinook salmon. The market squid fishery did undergo a dramatic increase from the mid-1970s to the 2000s, correlating with a decrease in abundance of squid in the salmon diet (Thayer et al. 2014). However, several years documented in the study, 1983 to 1986 and 2005 to 2007, coincide with crashes in the squid population that appear to be related to El Niño events, and the comparative take of the fishery during that time was relatively small. Therefore, though some Chinook salmon may be vulnerable to the loss of the California market squid as a key prey resource, particularly during the spring, it is unclear if the fishery is having a direct impact on the salmon diet at this time. More consideration should be given to potential impacts of the fishery on this vulnerable predator, particularly during the spring months when the salmon may rely on squid the most, though the fishery does not seem to be putting the Chinook salmon in any immediate danger.

Although management recognizes the important role of market squid in the CCLME (Porzio 2012) (PFMC 2011), an assessment of the ecosystem impacts of the market squid fishery has not been completed; therefore, the impacts of removing mature market squid on the ecosystem are unknown (Porzio 2012).

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch would like to thank consulting researcher and author of this report, Hannah Rosen, as well as several anonymous reviewers for graciously reviewing this report for scientific accuracy.

References

Brodeur, R.D, et al. (2007). Regional Comparisons of Juvenile Salmon Feeding in Coastal Marine Waters off the West Coast of North America. American Fisheries Society Symposium. 57: 183-203. Available at http://people.oregonstate.edu/~brodeuri/webpage%20pdf%20and%20docs/BrodeurAFS.pdf.

Caddy, J.F. and Sharp, G.D. (1986). An Ecological Framework for Marine Fishery Investigations. FAO Fisheries Technical Paper 283:152 p. Available at http://www.fao.org/docrep/003/t0019e/T0019E00.htm.

CDFW (2005). Market Squid Fishery Management Plan. California Department of Fish and Game. Available at: http://www.dfg.ca.gov/MRD/msfmp/entire.html

CDFW 2010. Market squid fishery closure notice. December 10 2010. Accessed at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=36555&inline.

CDFW 2011. Market squid fishery closure notice. November 10 2011. Accessed at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=39782&inline

CDFW 2013. New and Proposed Regulations. Amend Section 149 and subsection (a) of Section 149.1, Title 14, CCR, Commercial Taking of Market Squid. Accessed at: http://www.fgc.ca.gov/regulations/2013/index.aspx#149

CDFW (2016a). Market Squid Fishery Landings Data California Department of Fish and Game. Available at https://www.wildlife.ca.gov/Fishing/Commercial/Landings

CDFW (2016b). Regional MPA Statistics. Available at: https://www.wildlife.ca.gov/Conservation/Marine/MPAs/Statistics

CDFW (2018). Updating the MLMA Master Plan California Department of Fish and Game. Available at https://www.wildlife.ca.gov/Conservation/Marine/MLMA/Master-Plan

Chuenpagdee, R., Et al. (2003). Shifting gears: assessing collateral impacts of fishing methods in US waters. Front. Ecol. Environ. 1: 517-524. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.179.1589&rep=rep1&type=pdf

Collie, J. S., et al. (2000). A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology 69:785-798.

Dorval, E., P.R. Crone, and J.D. McDaniel. (2013). Variability of egg escapement, fishing mortality and spawning population in the market squid fishery in the California Current Ecosystem. Marine and Freshwater Research. 64:80-90.

Enticknap, B., et al (2011). Forage Fish: Feeding the California Current Large Marine Ecosystem. Oceana, Washington, D.C.

FDA (2016). The Seafood List. Available at http://www.accessdata.fda.gov/scripts/fdcc/index.cfm?set=seafoodlist&id=Loligo_opalescens&sort=SLSN&order=ASC&startrow=1&type=basic&search=squid

Field, J.C., et al. (2001). Toward a Fisheries Ecosystem Plan for the Northern California Current. CalCOFI Rep. 42: 74-87.

Fishbase (2016). Available at http://www.fishbase.org/summary/244

Foote, K. G., et al (2006.) Acoustic detection and quantification of benthic eggs beds of the squid Loligo opalescens in Monterey Bay, California. J. Acoust. Soc. Am. 119: 844-856.

Forsythe, J., N. Kangas, and R. T. Hanlon. (2004). Does the California market squid (Loligo opalescens) spawn naturally during the day or at night? A note on the successful use of ROVs to obtain basic fisheries biology data. Fish. Bull. 102: 389–392.

Hendrickson, L.C. (2017). Longfin inshore squid (Doryteuthis (Amerigo) pealeii) stock assessment update for 2017. Available at https://static1.squarespace.com/static/511cdc7fe4b00307a2628ac6/t/59073cc9be65945087783a84/1493646537

Hideaki, Kidokoro. et al. (2013). 2013 Japanese Flying Squid Autumn Cohort Biomass Estimation Report. Japan Sea National Fisheries Research Institute, FRA

Jackson, G. D., and M. L. Domeier (2003). The effects of an extraordinary El Niño event on the size and growth of the squid Loligo opalescens off Southern California. Marine Biology 142: 925-935.

Japanese Fisheries Agency (2015). Assessment of the autumn – spawning group of the squid in the year 2015 (In Japanese). [http://abchan.fra.go.jp/] [Date accessed: 24-Jul-2016]

Japanese Fisheries Agency (2015). Assessment of the winter – spawning group of the squid in the year 2015 (In Japanese). [http://abchan.fra.go.jp/] [Date accessed: 24-Jul-2016]

KION 2018. Monterey Bay dolphins narrowly escape squid net. Accessed at https://www.kion546.com/news/monterey-bay-dolphins-narrowly-escape-squid-net/734084884, December 5 2018.

Koslow, J. A. and C. Allen (2011). The influence of the ocean environment on the abundance of market squid, Doryteuthis (Loligo) opalescens, paralarvae in the Southern California Bight. CalCOFI Reports 52: 205-213.

LenFest (2012). Little fish big impact: A summary of new scientific analysis. Available at http://www.lenfestocean.org/~/media/legacy/lenfest/pdfs/online_fftf_summary.pdf?la=en

Lowry, M. S. and J. V. Carretta (1999). Market squid (Loligo opalescens) in the diet of California sea lions (Zalophus californianus) in southern California (1981-1995). CalCOFI Reports 40: 196-207.

Lutz, S. and Pendleton, L. (2001). Socio-economic study of the San Pedro historic purse seine fleet. USCFish.

Macewicz, B. J. (2004). Fecundity, egg deposition, and mortality of market squid (Loligo opalescens). Fish. Bull. 102: 306-327.

Marinovic, B. (2007). New Model Links Ocean Conditions to Squid Biomass. California Sea Grant Program.

Marinovic, B. (2003). Assessing the impact of climate change on the California squid fishery: an integrated approach. California Sea Grant Program 03-04.

Maxwell, M.R. (2004). Fishery dynamics of the California market squid (Loligo opalescence), as measured by satellite remote sensing. Fish. Bull. 102: 661-670

McClatchie, S., et al. (2016). Food limitation of sea lion pups and the decline of forage off central and southern California. Royal Soc. Open Sci. 3 150628; DOI: 10.1098/rsos. 150628.

McDaniel, J.M. (2015). Optimizing biological parameterization in the egg escapement model of the market squid, (Doryteuthis opalescens), population off California. NOAA-TM-NMFS-SWFSC-551.

Meyer-Löbbecke A, Debich AJ, Širovic A, TrickeyJS, Roch, MA, Carretta JV, Fraiser K, Wiggins SM, Hildebrand JA, Denzinger A, Schnitzler H-U, Baumann-Pickering S (2016). Noise from explosive deterrents used by California fisheries and possible effects on marine life. Poster presentation at the 4th International Conference on the Effects of Noise on Aquatic Life, July10-16, 2016, Dublin, Ireland. Available at http://baumann.ucsd.edu/posters/AN2016_Poster_Loebbecke.pdf

Meyer-Löbbecke A, Fraiser K, Simonis A, Reese F, Kim EB, Denzinger A, Schnitzler H-U, Baumann-Pickering S (2017). Squid as common target: Do areas with fishery-related explosions and dolphin foraging habitats in Southern California overlap? Poster presented at the 31st Annual Meeting of the European Cetacean Society, May 1-3, 2017, Middelfart, Denmark. Available at http://baumann.ucsd.edu/posters/Poster%20ECS%20Anna%20Meyer-Loebbecke.pdf

Miller, T.W. and Brodeur, R.D. (2007). Diets of and trophic relationships among dominant marine nekton within the northern California Current ecosystem. Fisheries Bulletin 105: 548-559.

Morejohn, V. G. (1978). The importance of Loligo opalescens in the food web of marine vertebrates in Monterey Bay, California. Department of Fish and Game Fish Bulletin 169: 67-98

NMFS (2012). FishWatch: US Seafood Facts: Market Squid. Available at http://www.fishwatch.gov/seafood_profiles/species/squid/species_pages/market_squid.htm

NMFS (2016). National Marine Fisheries Service - 1st Quarter 2016 Update Table A. Summary of Stock Status for FSSI Stocks. Available at http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2016/first/q1-2016-stock-status-tables.pdf

NOAA (2018). List of Fisheries for 2018. Available at https://www.fisheries.noaa.gov/national/marine-mammal-protection/list-fisheries-summary-tables

Okutani, T. and J. A. McGowan (1969). Systematics, distribution, and abundance of the epiplanktonic squid (Cephalopoda, Decapoda) larvae of the California current, April, 1954-March, 1957. Bulletin of the Scripps Institute of Oceanography 14: 1-90.

Perretti, C.T., Zerofski, P.J., Sedarat, M. (2016). The spawning dynamics of California market squid (Doryteuthis opalescens) as revealed by laboratory observations. Journal of Molluscan Studies 82: 37-42.

PFMC (1998). Appendix D: Description and identification of essential fish habitat for the coastal pelagic species fishery management plan. Available at http://www.westcoast.fisheries.noaa.gov/publications/habitat/essential_fish_habitat/coastal_pelagic_appendix_d

PFMC (2002). Amendment 10 to the Coastal Pelagic Species FMP: Limited Entry Fleet Capacity Management and Market Squid Maximum Sustainable Yield Control Rule. Pacific Fishery Management Council. Available at http://www.pcouncil.org/coastal-pelagic-species/fishery-managementplan-and-amendments/amendment-10/

PFMC (2010). Scientific and statistical committee report on pacific sardine stock assessment and coastal pelagic species management measures for 2011. Available at http://www.pcouncil.org/wp-content/uploads/I2c_SUP_SSC_NOV2010BB.pdf

PFMC (2011). Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation (SAFE). Pacific Fishery Management Council 12: 1-93. Available at http://www.pcouncil.org/coastal-pelagic-species/stockassessment-and-fishery-evaluation-safe-documents/

PFMC (2014). Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation (SAFE). Pacific Fishery Management Council 12: 1-93. Available at http://www.pcouncil.org/wp-content/uploads/2014_CPS_SAFE_Text_FINAL.pdf

PFMC (2017). Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation (SAFE). Pacific Fishery Management Council 12: 1-93. Available at http://www.pcouncil.org/wp-content/uploads/2017/05/CPS_SAFE_FINAL_May-2017.pdf

PFMC, 2017a. Agenda Item G.5.b: Supplemental CPSMT Report. PFMC meeting April 2017. Available at http://www.pcouncil.org/wp-content/uploads/2017/04/G5b_Sup_CPSMT_Rpt_Apr2017BB.pdf.

PFMC 2017b. Decision Summary Document, Pacific Fishery Management Council. April 7-11, 2017. Available at http://www.pcouncil.org/wp-content/uploads/2017/04/April2017DecisionSummaryDocumentFINAL.pdf

PFMC, 2017c. Assessment of the pacific sardine resource in 2017 for u.s. management in 2017-18. Appendix C in PFMC CPS SAFE Document May 2017. Available at http://www.pcouncil.org/wp-content/uploads/2017/05/Appendix-C-2017-sardine-assessment-NOAA-TM-NMFS-SWFSC-576.pdf.

Porzio, D (2012). Personal Communication. California Department of Fish and Game, Monterey, CA

Porzio, D. and B. Brady (2006). Status of the fisheries report: market squid. California Department of Fish and Game: 1-11.

Preti, A., et al. (2012). Comparative feeding ecology of shortfin mako, blue, and thresher sharks in the California Current. Environ. Biol. Fish 95: 127-146

Protasio, C.Q., A.M. Holder, and B.C. Brady (2014). Changes in biological characteristics of the California market squid (Doryteuthis opalescens) from the California commercial fishery from 2000-01 to 2012-13. California Fish and Game. 100: 276-288.

Ralston, S.,et al. (2018). Predicting market squid (Doryteuthis opalescens) landings from pre-recruit abundance. Fisheries Research 199: 12-18.

Reiss, C. S., et al. (2004). Investigating environmental effects on population dynamics of Loligo opalescens in the Southern California Bight. CalCOFI Reports 45: 87-97

Rodhouse, P.G.K.,et al. (2014). Environmental effects on cephalopod population dynamics: implications for management of fisheries. Adv. Mar. Biol. 67 : 99-223.

Sea Fare Group (2011). Quantification and Market Analysis of the Top 30 Seafood Species/Categories Consumed in the U.S. Prepared by Sea Fare Group for Monterey Aquarium Seafood Watch®, March 15, 2011

Sweetnam, D. (2011). Review of selected California fisheries for 2010: Coastal pelagic finfish, market squid, ocean salmon, groundfish, highly migratory species, Dungeness crab, spiny lobster, spot prawn, kellet's whelk, and white seabass. CalCOFI Reports 52: 13-35.77.1+1

Thayer, J.A., et al. (2014). Changes in the California Chinook salmon diet over the past 50 years: relevance to the recent population crash. Marine Ecology Progress Series 498: 249-261.

Van Diggelen, A. (2017). State of the California South Coast Supplemental Report: Market Squid. CDFW February 2017. Accessible at https://cnra-assets.s3.amazonaws.com/resources/5f658b3f-68be-4b44-9017-a1ee70986d77/cdfw_squid-spotlight_finaldraft.pdf

Van Noord, J.E. and E. Dorval. (2017). Oceanographic influences on the distribution and relative abundance of market squid paralarvae (Doryteuthis opalescens) off the Southern and Central California coast. Marine Ecology 38: e12433.

Vojkovich, M. (1998). The California fishery for market squid (Loligo opalescens). Calif. Coop. Oceanic Fish. Invest. Rep. 39:55-60.

Wells, B.K., et al. (2017). States of the California Current 2016-2017: Still Anything But "Normal" in the North. CalCOFI Rep., Vol. 58.

Yamashita, Norio, et al. (2013). Japanese Flying Squid Winter-cohort Biomass Estimation Report. Hokkaido National Fisheries Research Institute, FRA.

Young, M. A., et al. (2011). Seafloor mapping and landscape ecology analyses used to monitor variations in spawning site preference and benthic egg mop abundance for the California market squid (Doryteuthis opalescens). Journal of Experimental Marine Biology and Ecology 407: 226-233.

Zeidberg, L. D., et al. (2006). The fishery of the California market squid, Loligo opalescens (Cephalopoda, Myopsida), from 1981–2003. Fish. Bull. 104, 46–59.

Zeidberg, L. D., et al. (2011). Estimation of spawning habitats of market squid (Doryteuthis opalescens) from field surveys of eggs off Central and Southern California. Marine Ecology (2011): 1-11.

Zeidberg, L. D., et al. (2004). Egg masses of Loligo opalescens (Cephalopoda: Myopsida) in Monterey Bay, California following the El Niño event of 1997-1998. Bulletin of Marine Science 74: 129-141

Zeidberg, L.D. (2013). Doryteuthis opalescens, Opalescent inshore squid. In: Advances in Squid Biology, Ecology, and Fisheries. Part 1. pp 159-204. Nova Science Publishers, Inc. New York.