**Logic Chain Symposium October 2010 – Stressors and SMART objectives worksheet for LFS**

**Notes taken by J. Rosenfield**

**List of Stressors/Limiting Factors**

1. **Physical spawning habitat loss and modification**
2. **Degraded pelagic habitat for larval and early life stage LFS**
3. **Increased food Limitation due to food web suppression**
4. **Increased toxin concentrations**
5. **Increased nutrient concentrations and/or altered N:P ratios**
6. **Entrainment**
   1. **As relates to abundance/production**
   2. **As relates to spatial distribution**
7. **Predation[[1]](#footnote-1)**

**Stressors not addressed by BDCP**

1. **Temperatures in the West Delta and LSZ**
2. **Runoff Timing**
3. **Unimpaired Hydrology**
4. **Boat Traffic**
5. **Future Invasive Predators and Competitors**

**Stressor # \_\_:** Physical Spawning Habitat Loss and Modification

**BDCP Objective**: Increase extent and availability of quality LFS physical spawning habitat

**Relation to Global Objectives**: Increasing the extent/availability and quality of spawning habitat for longfin smelt may have positive effects on productivity and abundance.

**Indicator**: Spatial extent of quality habitats available for longfin smelt spawning. Attributes of “quality spawning habitat (i.e. what makes a habitat “quality spawning habitat”) remain to be defined as they are largely unknown at this time. The position and extent of spawning habitat is believed to track the position of the low salinity zone.

**Locations**: Suisun bay, Suisun Marsh, West Delta, lower Sacramento River, lower San Joaquin (historic spawning area)

**Timing (e.g. seasonality) of stressor reduction**: Spawning season roughly ~December -April

**Attribute**: Spatial Extent: Acreage of accessible habitat

Quality: Undefined as micro-habitat requirements are unknown. Further research in this ecosystem needed.

**Quantity or State**: Maintain/improve existing, and increase the areal extent of LFS spawning habitat that meets certain quality specifications (may be divided into “high”, “medium” and “low” quality or accessibility) by \_\_\_\_\_\_\_\_% or by \_\_\_ acres

**Confidence that “Quantity or State” are sufficient to attain objective** Unknown as the hypothesis that LFS are limited by physical spawning habitat substrate is undocumented and attributes of spawning micro-habitat are undefined.

**Time Frame** (defined herein as the time from implementation of CM’s or suites of CM’s til Objective may reasonably be attained). Use of newly created or improved spawning habitat substrate by spawning adults and larvae could be assessed within a few years. ~~Attainment of Objective would be assessed after several years in which the expectation would have been a population limited by spawning habitat availability prior to restoration.~~ Attainment of Objective would be assessed after implementation of habitat restoration and following several years (~5) years in which conditions would have been expected to limit spawning habitat prior to restoration.

Stressor #\_\_: Degraded pelagic habitat for larval and early life stage LFS

[Descriptive text here to incorporate potential effect of improved pelagic habitat quality on reduction in predation. Potential mechanisms = a) moving longfin smelt population away from habitats with high predator density b) reduced predator efficacy in higher quality environments.]

**BDCP Objective**: Increase the extent (overlap of acceptable parameters of key habitat variables) and improve quality of the physical/chemical attributes of longfin smelt pelagic habitat.

**Relation to Global Objectives**: Increasing the extent and improving the quality of the physical/chemical attributes of longfin smelt pelagic habitat (including transport/retention dynamics) will increase longfin smelt abundance and productivity.

**Indicator(s)**: 1) Volume of LFS’ preferred pelagic habitat conditions (e.g. temperature, depth, turbidity, salinity) during critical winter and spring periods

2) Magnitude and duration of flows that promote transport and retention of LFS (e.g. gravitational circulation) in the LSZ.

As described below, these are well-indexed by the variable “X2” (the 2ppt bottom isohaline) – the frequency distribution of X2 values in different months indicates the state of LFS pelagic habitat over time.

**Locations**: Low Salinity Zone (i.e. location changes depending on hydrology of a given year). Generally, in the West Delta or Suisun Bay and, less frequently San Pablo Bay.

**Timing (e.g. seasonality) of stressor reduction:** Winter-Spring (December-June)

**Attribute:** “X2” appears to index the extent of overlap of physical-chemical conditions supportive of spawning (age 2+), Age 1+, and larval LFS.

X2 also indexes the magnitude of hydrodynamics relevant to transport and retention of longfin smelt larvae.

**Quantity or State:** Exceedence curves for X2 may be used to define the desired quantity/state of this indicator. TBI (2010) identifies Delta outflows in Jan-Mar, Mar-May, and June that correspond to population growth (generation to generation increase in abundance indices) among longfin smelt. Flows (and corresponding X2 values) that produce a high likelihood (>50% chance) of inter-generational increase in abundance are to be met or bettered (more westerly) in at least 50% of years (i.e. in Normal, Above Normal, and Wet years). Because the population growth response to outflows (and X2) is linear/continuous, exceedence probabilities for flows that are more likely and less likely to produce growth must also be established as well (i.e., not all “good” years are equally “good”).

For example, TBI (2010) identifies other flow targets on a frequency exceedence basis; the corresponding X2’s are to be exceeded (X2 as far west or further) for at least those frequencies. The flows exceedences for different seasonal time-periods are as follows (these can and should be converted into X2 values):

|  |  |  |
| --- | --- | --- |
| **Months** | **Delta Outflow** | **To be exceeded \_\_% of years** |
| Jan-Mar | 2.5 MAF | 95% of years |
| 6.3 MAF | 60% of years |
| 10MAF | 40% of years |
| Mar-May | 2.5MAF | 87.5% of years |
| 6.3 MAF | 50% of years |
| 10 MAF | 25% of years |
| June | 250TAF | 75% of years |
|  | 508TAF | 50% of years |
|  | 1.2MAF | 25% of years |
| Jan-June | 3.2MAF | 95% of years |
|  | 6.3 MAF | 80% of years |
|  | 13.5MAF | 50% of years |
|  | 20MAF | 33% of years |

[Adaptive Management/Research may indicate whether Delta outflow or x2 is the better attribute]

**Confidence that “Quantity or State” are sufficient to attain Objective:** The long record of strong correlations between outflow/X2 and Delta smelt abundance indices and population growth suggests that the outflow/X2 values above are very likely to address ***these*** stressors related to the physical attributes of quality LFS pelagic habitat (other stressors identified in the LFS logic chain would, of course, still need to be addressed to contribute to recovery of this species).

**Time Frame:** Eight to ten years of flows that would be expected to produce inter-generation population growth should be sufficient to indicate whether this objective is adequate to relieve the stressor.

**Stressor # \_\_:** Increased food Limitation due to food web suppression

Pelagic fish habitat includes abiotic and biotic attributes. The abiotic aspects are described under the stressor “Degraded pelagic habitat for larval and early life stage LFS“. Generally, longfin smelt are a zooplanktivorous species that target larger zooplankton as they grow. The predominant low-salinity zone zooplankter small enough for larval longfin smelt to eat that co-occurs in time with their winter-spring larval period is *Eurytemora affinis*. Further seaward, other copepods including the *Acartia* spp. are also abundant and may be important prey. Juvenile longfin smelt likely continue to eat copepods during the summer and fall, but as the spring progresses into summer, the dominant species in the low-salinity zone change, so the species eaten by longfin smelt must also change. Juvenile longfin smelt increasingly incorporate larger zooplankton like mysids and amphipods into their diet as they grow. The interannual density of some of longfin smelt’s historical prey covaries with Delta outflow. In some cases the covariations changed after the overbite clam invasion. Given the winter-spring occurrence of longfin smelt’s larval stages, it is not likely that larval prey densities have been greatly affected by the overbite clam, because this clam’s densities are depleted by predators during winter. The clam densities do not rebound until early summer. However, the ability of the low-salinity zone to support longfin smelt production during summer and fall has potentially been impacted by overbite clam grazing.

**BDCP Objective**: Increased density of LFS preferred prey

**Relation to Global Objectives**: Abundance and productivity are expected to increase with an increasing LFS food supply

**Indicator**: 1) longfin smelt preferred prey items (mysids, Eurytemora, amphipods, *Psuedodiaptomous*, etc)

(additional system-wide metrics include: 1) individual growth rates or condition index to understand extent of food limitation and 2) diet studies -- to determine if the LFS diet has been affected by restoration-related impacts to food supplies.

**Locations**: the low salinity zone (0-6psu)

**Timing (e.g. seasonality) of stressor reduction:** Food limitation may be problematic year-round. Late-spring (june) through fall appear to be the most likely time that a limitation on food production would result from clam-based (grazing) limitation on the food web.

**Attribute**: Density of prey and at least one of the following

1. individual growth rates or proportion of maximum ration attatined (Pmax)
2. condition index and
3. diet studies -- to determine if the increase in food translates to decrease in food limitation

**Quantity or State**: A 10x increase in prey density would be required, at a minimum. Generally, prey-limited predators are expected to display linear population increases in response to logarithmic increases in their prey bas. So a 10x increase in density of key prey items might produce on the order of a doubling of the LFS (other factors being equal) based on simple trophic transfer relationships found in most food webs. [Importantly, the committee did not determine what level of increase in the LFS population would be required].

Alternative basis for objective might be to identify prey density during historical period of desired LFS abundance (e.g. 1967-1984) and establish this as the objective.

**Time Frame**: Expectation of time required to attain objective varies with type of conservation measure employed, for example:

*If ammonium concentration is the limit on prey density*, effectiveness of ammonium control measures could be evaluated within 1 year of bringing ammonium concentration in the LSZ below a critical threshold when that would otherwise have been exceeded (without ammonium control measures). ~5 years necessary to fully measure and evaluate the effect.

*If shallow tidal physical habitats limit prey density*, then the signal:noise ratio should continually decrease over the life of the permitted project. Team felt the objective could be evaluated within 1 to several years following full implementation (~65,000 ac) of shallow tidal habitat restoration (depending on evolution of tidal habitat characteristics). Several years of observation would be necessary to measure and evaluate the effect post-implementation; thus (given current implementation schedule) ~50 years to implement sufficient acreage and distribution of restorations to determine whether they substantially address this stressor. Local increases in food (adjacent to tidal habitat restorations,) could be detectable with less marsh acreage restored and thus much sooner. Recommend evaluating efficacy of habitat restoration to low-salinity zone food web supplementation after ~14,000 ac have been restored (i.e. beginning of Early long term) and continue to study restoring tidal marsh projects already undergoing restoration.

*If freshwater flows limit prey production* (perhaps through interaction with stressor categories identified above), then improvements in actual outflow relative to unimpaired hydrology might be detectable within ~5+ years of flow modification implementation. Detection requires construction of an unimpaired outflow:prey density relationship(s) for the baseline period (to show how much food was produced under given climate driven conditions) – increases in actual outflow for given unimpaired flow conditions would be expected to produce increased supply of prey relative to unimpaired flow conditions. [Should be noted that increased flow reduces prey *density* (because of the increase in the numerator), thus the objective might be redefined in terms of prey abundance or flux through the system to correct for the combined effect of prey base stimulation and “dilution”.]

**Confidence that “Quantity or State” are sufficient to attain Objective:**

Differs with different stressors

* the hypothesis re: ammonium levels and food web suppression has been described in published literature (e.g. Dugdale). The impact of alleviating this potential primary producer on secondary consumer organisms (two steps up the food web from primary producers) is unclear
* the hypothesis that increases in certain types of shallow water habitats will increase food supplies in the pelagic zone is untested and the subject of concerns related to magnitude, timing, and type of materials exported (or import) as well as whether the exported “food” will reach the deeper, pelagic habitats where this species lives (e.g. DRERIP Reviews).
* the hypothesis that some zooplankton/shrimp that longfin smelt feed on will be increased by increases in freshwater flows is supported by long-term, significant, high-magnitude positive relationships with outflow (e.g. Kimmerer 2002 currently amd Jassby et al 1995, historically)

**Potential covariate in unmanaged stressors**: unimpaired hydrology (food abundance sensitive to outflow). In other words, effectiveness of non-flow related measures is evaluated against expectation of food web productivity given the relationship between prey density and hydrology in a given year (modifications to actual hydrology as well as other physical habitats are both expected to play a role in food web productivity).

**Stressor # \_\_:** Increased toxin concentrations

(pyrethroids, Organophosphates, surfactants)

**BDCP Objective**: Reduce toxic compound concentrations to below identified thresholds that impede productivity of the LFS food supply (ie, that produce detectable effects on those things that LFS eat)

**Indicator:** Concentrations of identified toxins and zooplankton bioassays

**Locations:** Will vary by toxin. They should be measured where they would potentially effect longfin smelt. Pyrethroids would be measured in sediment, organophosphates in the water column, etc. Some (but not all) potential toxins might be measured as concentration in fish tissues; in this case it would be necessary to correlate body-burden with fish condition, performance, and fertility.

**Timing (e.g. seasonality) of stressor reduction**: Step 1: determine when/where food limitation is occurring. Step 2: evaluate water toxicity indicators at those times/places relative to other areas

**Attribute:** Intentionally left blank [unknown]

**Quantity or State:** Intentionally left blank [unknown]

**Time Frame:** Intentionally left blank [unknown]

**Confidence that “Quantity or State” are sufficient to attain Objective:** The current effect of toxins on the populations of organisms that LFS eat is unknown. Therefore, precise description of this stressor-reduction objective for this species is unlikely at this time.

**Stressor # \_\_:** Increased nutrient concentrations (ammonium)

and/or altered N:P ratios

**BDCP Objective**: Reduce nutrient concentrations to below identified thresholds that impede productivity of the LFS food supply (ie, that produce detectable effects on those things that LFS eat) and/or that support levels of toxic organisms (e.g. microsystis) that inhibit attainment of LFS distribution objectives.

**Relation to Global Objectives**: Limitation of the food supply potentially constrains LFS abundance and productivity. If the limitation is regionally specific, foodweb limitations may constrain LFS distribution as well.

Nutrient levels that encourage growth of toxic organisms like *microcystis* may be limited LFS distribution.

**Indicator:** Concentrations of identified nutrients; intensity of Microcystis bloom? Restoration of spring-summer diatom blooms…

**Locations:** Suisun Bay in the late spring-fall. .

**Timing (e.g. seasonality) of stressor reduction**: May-Octoberish

**Attribute:** Diatom blooms, zooplankton population responses

**Quantity or State:** Intentionally left blank [unknown]

**Time Frame:** May-Octoberish [unknown]

**Confidence that “Quantity or State” are sufficient to attain Objective:** The current effect of nutrients on the populations of organisms that LFS eat is unknown. Some research has indicated levels of ammonium that may inhibit production at the base of the food web (phytoplankton), though if/how improving phytoplankton growth in certain years will transfer to LFS is unknown. The ammonium threshold (~4 umolar?) is fairly certain; concentrations below this are not expected to inhibit primary production.

**Stressor # \_\_:** Entrainment

Entrainment of longfin smelt occurs when the hydrodynamic influence of water exports overlaps with longfin smelt spawning and early rearing habitat, and draws in pelagic larvae, juveniles or adults, or miscues juveniles or adults and they swim in the direction of export flow. Winter entrainment of large juveniles and adults in south Delta export flows, indexed by salvage, occurs almost exclusively during low outflow years (Sommer et al. 1997, CDFG 2009b), when net flows in Old and Middle River channels are strongly negative or directed toward the export pumps (Grimaldo et al. 2009). In late-winter and spring, entrainment of larvae as modeled by surface oriented particles in the south Delta increases with net negative OMR flows (CDFG 2009b) and similarly salvage of small juvenile longfin smelt increases as OMR flows become more negative (Grimaldo et al. 2009 and CDFG 2009b).

**BDCP Entrainment Objective (A)**: *For winter protection of reproductive adults*: combined SWP and CVP December through February salvage of juvenile and adult longfin smelt shall not exceed 3 times the value of the Fall Midwater Trawl longfin smelt index (all ages) from the previous September through December.

*For winter spring protection of larvae and early juveniles*: Larvae entrainment modeled by surface oriented particles (DSM2 particle tracking model) shall not exceed 10 % of particle from the San Joaquin River sampling station 812, while longfin smelt larvae are being detected at 8 of 12 sampling locations in the San Joaquin River and south Delta (see SWP ITP).

**Relation to Global Objectives**: Reducing entrainment of reproductive, larval, and early juvenile longfin smelt will increase productivity (survival and total egg production)

**Indicator**: See above

**Locations:** Salvage measured at Project Diversions and impingement (or relevant measure) at Mirant Power Plant. Stock of spawning aged fish measured by FMWT and/or other survey at existing survey stations.

**Timing (e.g. seasonality) of stressor reduction**: Dec-June. LFS entrainment is a greater concern during low outflow periods when X2 is nearer the south Delta export facilities.

**Attribute: X2 and Qwest , andOMR flows**

**Quantity or State**: See above.

**Time Frame**: Measure efficacy should be detectable in first few years after implementation in which low outflow conditions would make LFS susceptible to entrainment. Attainment of objective would be evaluated after several years of “susceptible conditions”.

**Confidence that “Quantity or State” are sufficient to attain Objective:** Needs further documentation – see K. Newman Life Cycle model? In particular, pre-screen mortality estimates for LFS should be studied.

**BDCP Entrainment Objective (B):** Spawning and larval migration spatial extent will not be limited by entrainment mortality or diversion-related impacts to habitat

**Relation to Global Objectives:** Reducing entrainment of spawning, larval, and early juvenile longfin smelt in the lower San Joaquin River will allow for increased spatial distribution of spawning

**Indicator: X2 and OMR flows**

**Locations:** Old and Middle River flow gauges on either side of Bacon Island and QWEST – the flow estimate for the San Joaquin River at Jersey Point in the DAYFLOW database (where flow is currently measured)

**Timing (e.g. seasonality) of stressor reduction**: Dec-June. LFS entrainment is a greater concern in years when outflow conditions place X2 close to the south Delta export facilities.

**Attribute**: Net average flow in Old and Middle River and at Jersey Point

**Quantity or State**: OMR Flows not to be more negative than -5,000 cfs December – June (spawning-larval period)

**Time Frame**: Measure efficacy could be modeled prior to plan implementation. Groundtruthing this estimate in the field requires some substantial new sampling/monitoring. Effect would be expected to materialize in concert with restoration efforts in the south Delta including improved flows and reduction in *Egeria*.

**Confidence that “Quantity or State” are sufficient to attain Objective:** Conceptual model for LFS indicates that continued entrainment-related mortality in the South Delta could be a factor in declining detection for spawning activity in that region. Research needs re: LFS reproductive site fidelity.

1. The work team acknowledged that predation could not be framed with a *measureable* objective for this species now or in the near future and that the greatest impacts on predation (if it is indeed a major stressor) would occur through modifications of physical-chemical habitat [↑](#footnote-ref-1)