Appendix L. Alkali Fly Productivity Model

The alkali fly productivity model (Figure L-1) provides an essential tool for predicting the effects on the alkali fly population of various Mono Lake elevations resulting from alternative management scenarios. Using available lake bathymetry and alkali fly data for model input and calibration, this population model compares the relative seasonal abundance of aquatic lifestages at different projected lake levels. The spreadsheet model estimates monthly alkali fly average biomass and cumulative production at environmental conditions corresponding to lake elevations from 6,350 to 6,420 feet. Summary results are graphically displayed to allow comparison between EIR alternatives.

MODEL ORGANIZATION AND USE

The alkali fly production model, POPFLY.WK1, was created in LOTUS 1-2-3, Release 2.3, for use on most personal computers. The spreadsheet is organized as a series of interconnected tables with progressive calculations as shown in Figure L-2. The first table is an input area, where input parameters are specified and adjustment factors calculated. The second table consists of alkali fly lifestage development times, sizes, and mortalities as functions of salinity and temperature. Temperature coefficients for each lifestage development time also are found in this table. The third table contains two-dimensional (2D) geometric means of alkali fly lifestage density data collected by Dr. David Herbst from six locations at Mono Lake in 1991. These data provide initial values of population densities for input into the model's daily calculation table and are used for calibrating the daily estimates of population densities. The fourth table calculates daily lifestage densities, biomass, and production per square meter for a specified lake elevation. Monthly and seasonal integrated production of total third instars and dislodged pupae, and monthly and seasonal average biomass of all lifestages for the entire lake, are computed and output to a fifth table, the lake summary table. Input conditions, temperature and salinity effects, daily estimates at a particular elevation, and monthly summary values for the range of elevations can be displayed with various graphs.

Instructions for using the model are found at the top of the spreadsheet. The model is run by pressing the "ALT" and "A" keys simultaneously, which activates an user-interactive macro. The macro allows the user a choice between daily or summary outputs and enables the user to alter various model inputs before running the model. Experienced users can change input parameters within the input tables without stepping through the macro.

MODEL DEVELOPMENT

The alkali fly productivity model was developed using several types of data for input and calibration: Mono Lake bathymetry and hard substrate data, alkali fly density data, and relationships between fly growth and mortality for each aquatic lifestage with environmental factors such as temperature, salinity, food availability, and substrate. The above data are contained within the data file spreadsheets BATHY.WK1 and FLYDATA.WK1. Summarized data necessary for model input and calibration were copied to the assessment model spreadsheet.

Bathymetry and Hard Substrate Data

BATHY.WK1 provides data on lake elevation, area, volume, salinity, and available fly habitat. It combines data from the PELAGOS Corporation (PELAGOS), Dr. Scott Stine, Dr. David Herbst, and Jones & Stokes Associates.

PELAGOS provided a bathymetry map of Mono Lake and a computer-generated table of lake area and volume corresponding to each lake elevation. A surface and subsurface topographical survey of Mono Lake was conducted by PELAGOS in August 1986 for LADWP employing a Mini-Ranger III navigation system. The lake was mapped below 6,370 feet at 5-foot contour intervals. Because the water level at the time of the survey was 6,380.7 feet elevation and the survey vessels had to maintain a certain distance from the shore, survey data near the lake perimeter (between 6,370 and 6,380 feet elevation) had the lowest accuracy. Contours from 6,375 to 6,330 feet elevation were mapped at 5-foot intervals using photogrammetric mapping compiled by Pacific Western Aerial Surveys (1982). Contours above 6,430 feet elevation were interpolated from preliminary U.S. Geological Survey (USGS) 7.5-minute quadrangle mapping (1982) for visual presentation only and were represented at 20-ft contours. Lake area (acres) and volume (acre-feet) were computer-generated for each foot of lake elevation based on the topographical data.

Jones & Stokes Associates compiled a map using a geographic information system (GIS) (ARC-INFO) system by combining contours from the PELAGOS map with data from additional aerial and ground surveys. The GIS map, which was verified by ground surveys, ranges from 6,320 feet elevation to 6,440 feet elevation and is more accurate than the PELAGOS map at contours above 6,365 feet elevation. However, the comparison with PELAGOS results is generally close for total and incremental lake area; the location of the elevation contours is the major difference. The Mono Lake bathymetry map is shown in Figure L-3. Jones & Stokes Associates smoothed the PELAGOS areas and volumes to eliminate variability in the 1-foot incremental areas. Salinity (grams per liter [g/l] of total dissolved solids [TDS]) as a function of lake volume was calculated assuming a total lake salt content of 285 million tons.

Stine approximated locations and densities of various types of soft and hard substrate on a map (1:24,000) provided by Jones & Stokes Associates, based on his extensive knowledge of Mono Basin geology and numerous surveys of the area. Incremental hard substrate areas of tufa, pumice bedrock, and beachrocks were planimetered by Jones & Stokes Associates from 6,300 feet elevation to 6,440 feet elevation. Areas between 6,300-6350 feet elevation were planimetered in 10-foot contour increments and areas between 6,350-6375 feet elevation were planimetered in 5-foot contour increments using the PELAGOS base map. Areas between 6,375-6,420 feet elevation were planimetered in 5-foot contour increments and areas between 6,420-6,440 feet elevation were planimetered in 10-foot contour increments using the Jones & Stokes Associates base map. In some steep areas, 10- to 20-foot contour increments were the highest resolution that could be achieved.

The 2D incremental substrate areas were then calculated by Jones & Stokes Associates with no consideration of slope. Bedrock and beachrocks are flat substrates covering almost 100% of their respective areas, and their planimetered areas were considered to be their 2D areas. Pumice areas consist of irregular-sized blocks scattered over areas otherwise covered by mud or sand. Stine provided a rough estimate of the densities of these blocks and their 2D and 3D areas. Jones & Stokes Associates computed the 2D flat pumice areas based on these estimates. Although tufa towers are highly variable in height, width, and coverage, their planimetered areas were considered to be identical with their 2D areas. The distribution of hard substrate could be determined only at a moderately low level of accuracy (±20%). The location and extent of planimetered hard substrate types are shown in Figure L-3.

The 2D incremental hard substrate areas were further divided into 1-foot contour incremental areas assuming equal area increments. Incremental soft substrate areas were calculated as incremental hard substrate area subtracted from the incremental total lake area at each elevation. A relationship showing declining alkali fly densities with increasing depth (Herbst and Bradley 1990) was used to determine suitable fly habitat to a depth of 32 feet for each foot of elevation. Hard substrate is considered to provide the maximum alkali fly densities and relates to depth exponentially as follows:

$$EHA = \sum_{d=0}^{32} (IHA \times e^{(-0.075\,d)})$$

where

EHA is the effective hard substrate area in acres,
d is the depth of the water column in feet, and
IHA is the incremental hard substrate area in acres at a depth of **d** feet.

Soft substrate is considered to provide an assumed fraction (5%) of maximum alkali fly densities and relates to depth linearly as follows:

$$ESA = \sum_{d=1}^{32} (ISA \times (1 - d/32)$$

where

ESA is the effective soft substrate area in acres,
d is the depth of the water column in feet, and
ISA is the incremental soft substrate area in acres at a depth of **d** feet.

The total effective habitat area at a given lake elevation is the depth-weighted hard substrate area increased by a perimeter of high-quality soft substrate area (assumed to be 10% of the depth-weighted hard substrate area) and an assumed fraction (5%) of the depth-weighted soft substrate area. Figure L-4 shows the pattern of effective habitat area for elevations between 6,350-6,420 feet.

USGS lake elevation; smoothed PELAGOS volume, area, and incremental area; and Jones & Stokes Associates salinity, incremental hard substrate area, depth-weighted hard, soft, and total substrate area, and the percentage of depth-weighted hard to total substrate area was copied into the POPFLY.WK1 spreadsheet. These data are part of the summary lake elevation table and provide input to the model to locate salinity and suitable habitat area for a given elevation. These values are given in Table L-1.

Alkali Fly Data

Alkali fly data are contained within the FLYDATA.WK1 spreadsheet, which provides the results of three interrelated projects completed by Herbst in 1991 (Herbst 1992): collection of field density data on alkali fly lifestage during the growing season, microcosm experiments to study the effects of salinity on the fly population, and collection of field drift data to determine the timing and extent of drift.

Field Density Data

Methods. Mono Lake field abundance data were gathered by Herbst from April 30 to October 15, 1991, in 11 sampling excursions to six selected sites around Mono Lake: North Land Bridge, Black Point Tufa Shoals, Old Marina, Lee Vining Tufa Grove, South Tufa Grove, and Willow Spring (Figure L-3). These are generally hard substrate areas that normally contain high densities of alkali flies. Multiple samples (usually eight) were collected from various types of soft and hard substrates on each sampling trip. A total of 1,052 samples were collected and analyzed. Hard substrate consisted of tufa, pumice, gaylussite, mudshale, alluvium, and sandstone beach pavement and was sampled by retrieving a piece of the substrate. Longest length and perimeter of the hard substrate were noted to calculate the 2D projected surface area. 3D exposed surface areas were found by wrapping the exposed rock area with aluminum foil and calculating the area by weighing the foil. Soft substrate consisted of sand and mud in vicinity of hard substrate (considered high-quality soft substrate because the density of larvae is higher on soft substrate close to hard substrate) and was sampled with a 4-centimeter (cm)-diameter corer. The number of animals for aquatic lifestages (i.e., eggs, first instars, second instars, third instars, full pupae, and empty pupae) in each sample was recorded.

Jones & Stokes Associates further analyzed Herbst's data to estimate 2D densities of the various lifestages per square meter (individuals per square meter [ind/m^2]) by dividing the individuals per sample by the 2D surface area of the sample. The geometric and arithmetic means of 2D lifestage densities per site were found by averaging the densities calculated from multiple samples taken on the same date at that site.

Results. Both arithmetic and geometric means of 2D lifestage densities over time are presented by site and substrate type (Figures L-5 through L-10). Figures L-5A and L-5B show geometric mean density of each lifestage on hard and soft substrates at site 1 (North Land Bridge). The peak density of pupae occurred on September 24 (day 267) with 97,000 ind/m^2 on hard substrate, the highest pupae density measured on any site and more than twice the average pupae density of 40,000 ind/m^2 on hard substrate. Almost no pupae were observed on soft substrate at site 1 or any other site. The peak density of third instars occurred during September 4 (day 247) with about 33,000 ind/m^2 on hard substrate. Third instar density on the soft substrate was considerably lower but peaked at the same time as the hard substrate with about 6,000 ind/m^2. These third instar densities and peak periods were typical for most sites. Densities of second instars on hard substrate climbed steadily and peaked at 10,000 ind/m^2 at the end of the season, whereas second instars on soft substrate peaked at 6,000 ind/m^2 on September 4 (day 247). Site 1 had the lowest second instar densities on either soft or hard substrate of any site. Densities of first instars on hard and soft substrate peaked earlier (day 220) at 10,000 and 1,500 ind/m^2, respectively, which is low compared to other sites. Egg densities on hard substrate reached a maximum of 30,000 ind/m^2 on August 7 (day 220). On soft substrate, egg densities at site 1 were lower than at any other site (less than 1,000 ind/m^2) throughout the season.

Figures L-6A and L-6B show geometric mean density of each lifestage on hard and soft substrates at site 2 (Black Point). Pupae were observed at densities of 20,000-50,000 ind/m^2 on hard substrate, which is fairly representative of most sites. Third instars were less abundant than pupae with densities of 10,000-20,000 ind/m^2 throughout the season. The most abundant lifestage on soft substrate was second instars at about 10,000-20,000 ind/m^2, the highest densities seen on soft substrate. Site 2 also had the highest densities of first instars on soft substrate at 15,000 ind/m^2. Soft substrate third instar densities were only 5,000-10,000 ind/m^2, a typical value. Egg densities were slightly above average, peaking at 23,000 ind/m^2 for hard substrate and 9,000 ind/m^2 for soft substrate.

Figures L-7A and L-7B show geometric mean density of each lifestage on hard and soft substrates at site 3 (Old Marina). Densities of all lifestages on both soft and hard substrate were consistently among the highest measured. Pupae on hard substrate peaked in the end of September (on day 267) at about 93,000 ind/m^2, with a smaller peak in the end of July (on day 205) of 40,000 ind/m^2. Double peaks of pupae were seen at several sites. Third instars on hard substrate slowly increased to 33,000 ind/m^2 by September 4 (day 247). Third instars on soft substrate reached 25,000 ind/m^2 on August 7 (day 220), by far the highest value measured.

Figures L-8A and L-8B show geometric mean density of each lifestage on hard and soft substrates at site 4 (Lee Vining Tufa Grove). Lifestage density patterns at site 4 were typical. Pupae peaked at 65,000 ind/m^2, while third instars slowly increased from 20,000 to 35,000 in September on hard substrate. On soft substrate, third instars peaked in the beginning of August (day 220) at 7,000 ind/m^2.

Geometric mean density of each lifestage on hard and soft substrates at site 5 (South Tufa Grove) are shown in Figures L-9A and L-9B. Values are similar to those from other sites. On hard substrate, pupae slowly increased to 55,000 ind/m^2 in September. Third instars peaked slightly earlier in the beginning of September at 33,000 ind/m^2. On soft substrate, third instars peaked in July at 8,000 ind/m^2.

Figures L-10A and L-10B show geometric mean density of each lifestage on hard and soft substrates at site 6 (Willow Spring). With the exception of egg densities measured at 170,000 ind/m^2 on hard substrate in the end of July (day 205), this site exhibited low to average density values. Pupae and third instars on hard substrate remained at 5,000-15,000 ind/m^2 throughout the season. Third instars on soft substrate peaked in the end of July (day 205) at 5,000 ind/m^2.

Both arithmetic and geometric 2D overall average densities from the six sites were calculated and graphed for each lifestage and substrate type. Figures L-11a and L-11b show overall geometric mean density of each lifestage on hard and soft substrates. Pupal densities on hard substrate peaked in the end of September at 40,000 ind/m^2, while no pupae were found on soft substrate. Third instar densities reached a maximum of 25,000 ind/m^2 on hard substrate and 7,000 ind/m^2 on soft substrate. Third instar densities on soft substrate peaked at the end of August (day 234), approximately 2 weeks earlier than third instar densities on hard substrate, which peaked in early September (day 247). Second instar densities on soft substrate reached a maximum of 4,500 ind/m^2 and persisted at that level for the remainder of the season. On hard substrate, second instar densities increased throughout the season to a peak in October of approximately 27,000 ind/m^2.

Data Application. The 2D geometric means of the hard and soft substrate densities of the various aquatic lifestages for each of the six stations, as well as for the means of all stations, were copied into the POPFLY.WK1 spreadsheet. These data provide initial densities of the individual lifestages and allow calibration of simulated densities with actual observed densities.

Microcosm Experiments on Salinity Effects

FLYDATA.WK1 also contains the results of Herbst's microcosm experiment in which the effects of varying salinity on alkali fly abundance and mortality was researched. Microcosms are large aquariums where the ecological effect of changing environmental variables such as salinity can be studied. Twenty 500-liter tanks were filled with Mono Lake water adjusted to 50, 75, 100, and 175 g/l salinity (four tanks for each salinity level) and inoculated with a known population of alkali flies. The tanks were covered with sand (soft substrate) on which concrete blocks (10 x 7 x 4 cm) were placed. The concrete blocks constituted artificial hard substrate. All tanks were sampled twice; 10 samples of soft and hard substrate from each tank were collected on day 30 (September 6) and on day 60 (October 6) after the inoculation. The density per lifestage per sample and the number of dead third instars were recorded.

Jones & Stokes Associates calculated 2D densities and arithmetic and geometric mean densities for tanks with identical salinities per date using the procedure described above for the field data. The microcosm data were indirectly used in the assessment model to verify modeled salinity effects corresponding to various lake elevations.

Field Drift Data

Alkali fly drift estimates were collected during 1991 by Herbst. Littoral drift, consisting of floating larvae, pupae, and adults, was sampled using a boat-towed floating net with a sampling width of 65 cm and a sampling depth of 55 cm. Distance and volume sampled were measured with a current meter. Tows were typically 3 minutes in duration and covered a distance of 50-100 meters at UC Santa Barbara brine shrimp sampling stations (Figure L-3). One surface tow at each of 10 stations was conducted biweekly from May through October. Near-shore phalarope feeding areas at the northeast edge of the lake (Figure L-3) also were transected from August 28 to 30 (days 241-243), when phalaropes were most numerous.

Open water drift data were analyzed by Jones & Stokes Associates in FLYDATA.WK1, with summary results included in POPFLY.WK1. The distribution of third instars, pupae, and adults in the drift is shown in Figure L-12. Drift consists mainly of third instars until the end of July through the beginning of September when pupae become the dominant lifestage. Adult flies represent a small fraction of the drift through most of the season, except August. Drift was present in patches because of wind and circulation patterns. Highest drift densities observed were 5-10 ind/m^2 in foam lines and 30-50 ind/m^2 at near-shore circulation convergence areas where phalaropes feed. Phalarope feeding areas had average drift densities of 5-8 ind/m^2. Open water drift densities were much lower. Figure L-13 shows the 2D densities of third instars and pupae per square meter (ind/m^2) in open water drift. Typical averages were 0-0.5 ind/m^2 throughout the season, except in August when a peak average of 1-2 ind/m^2 was found. Adult flies were not included in Jones & Stokes Associates' analysis of Herbst data because the assessment model does not calculate adult fly densities. The open water drift data were used in the assessment model to estimate reasonable values for drift throughout the growing season.

Other Data

Daily temperatures used in the model were measured at site 3 (Old Marina) by Jones & Stokes Associates at a depth of 0.5 meter. Herbst provided mean fully developed lifestage dry weights (milligrams per liter [mg/l]) and mean development times of each lifestage at 50, 100, and 150 g/l salinity from 1991 laboratory data (Herbst 1992). Herbst also furnished mean development times as a function of temperature (Herbst 1990, Court Testimony). Mean fully developed weights of each lifestage were used to calculate fly biomass and production per square meter of soft and hard substrates. For first, second, and third instars, mean fully developed weights were multiplied by 0.5 to approximate a middle-of-stage weight. Production of third instars and pupae were calculated from fully developed weights. A table of mean weights, development time, and mortality for selected salinities was created using interpolation of the 1991 laboratory data (Table L-2).

MODEL ASSUMPTIONS AND CALCULATIONS

The model (POPFLY.WK1) calculates daily density, biomass, and production for each lifestage for a square meter of ideal hard substrate between May 1 and October 31. Temperatures are too cold for significant growth in other months, and 1991 field data were collected during this period.

Development Rate and Time Estimates

The model estimates the development rates for each lifestage as the inverse of the development times. The development times are estimated as functions of temperature and salinity at each lifestage. Table L-2 shows the estimated development times for a range of temperatures. Development times of each lifestage is modeled as:

$$\text{DT (lifestage)} = a \times e^{(-b/T)} \times \text{SF (lifestage)}$$

where

DT (lifestage) is the development time in days,
T is the water temperature on that day,
SF (lifestage) is the salinity adjustment factor, and
a and **b** are coefficients chosen to achieve reasonable development times.

Figure L-14 shows development time as a function of temperature for each lifestage assuming a salinity of 100 g/l. These temperature functions are based on pupal development time experiments conducted by Herbst. The pupal development time increased from 10 days at 25°C to 29 days at 15°C. Development is considered not to occur at temperatures below 10°C. Development times of all other lifestages increase proportionally to pupal development times. The development times at 20°C are assumed to be 3 days for eggs, 4 days for first instars, 7 days for second instars, 15 days for third instars, and 15 days for pupae. Daily temperatures are used to estimate development times for each lifestage.

Development times for larval instars are considered salinity dependent, whereas eggs and pupae are assumed to be insulated from salinity effects. Figure L-15 shows development times of the various aquatic lifestages as a linear function of salinity assuming an ambient temperature of 20°C. For first instars, development times increase linearly from 3.6 days at 50 g/l salinity to 4.7 days at 150 g/l salinity. Development times for second instars are 6.3 days at 50 g/l salinity and 8.2 days at 150 g/l salinity. For third instars, development times increase from 10 days at 50 g/l to 20 days at 150 g/l. Figure L-16 shows 1991 field temperatures measured at Old Marina and the corresponding lifestage development times at salinity 92 g/l (elevation 6,375 feet). Very little development occurs at any lifestage at temperatures below 15°C.

Egg Density Estimates

Daily egg density is estimated with an empirical function of temperature to match the observed average hard substrate egg density pattern during 1991. The equation for egg density is given below:

$$N\ (\text{eggs}) = 0.3 \times (T - 7)^{\wedge 4}$$

where

N (eggs) is the density of eggs in ind/m^2 and
T is the water temperature on that day.

Daily estimated egg, first, second, third, and pupal densities at elevation 6,375 feet (92 g/l salinity) are shown in Figure L-17. Eggs were most abundant in July and August when temperatures were approximately 20°C. The number of eggs hatching each day to become first instars is simply the egg density divided by the development time multiplied by percent hatching success:

$$H\ (\text{eggs}) = N\ (\text{eggs})/DT\ (\text{eggs}) \times (1 - MF\ (\text{eggs}))$$

where

> **H (eggs)** is the number of eggs hatching each day,
> **MF (eggs)** is the mortality fraction, and
> **(1 - MF (eggs))** is the hatching success.

Egg Hatching Success Estimates

The assessment model version at elevation 6,375 feet (92 g/l salinity) indicates that a total of approximately 320,000 eggs/m^2 were hatched during the year assuming 100% hatching success. Egg hatching success is assumed to decrease linearly with salinity from 80% per day at 50 g/l salinity to 60% per day at 150 g/l salinity. At the lowest simulated lake elevation of 6,350 feet (147 g/l salinity), approximately 190,000 eggs/m^2 hatched (59% hatching success). At the highest lake elevation of 6,420 feet (46.5 g/l salinity), approximately 256,000 eggs/m^2 hatched (80% hatching success). The model assumes that adult densities and fecundity are not affected by salinity, so the same empirical egg pattern is used for all lake levels.

Instar Mortality Rate Estimates

Daily first instar density is calculated as the previous day's density plus the hatching eggs minus the first instars that develop into second instars and minus the first instars lost to salinity controlled mortality:

$$N\ (\text{first instars})_{i+1} = N\ (\text{first instars})_i \times (1 - 1/DT\ (\text{first instars})_{i+1} - MF\ (\text{first instars})) + H\ (\text{eggs})$$

An initial first instar density is obtained from selected field data on April 31. Second, third, and pupal densities are calculated similarly:

$$N\ (\text{second instars})_{i+1} = N\ (\text{second instars})_i \times (1 - 1/DT\ (\text{2nd instars})_{i+1} - MF\ (\text{second instars})) + N\ (\text{first instars})_i \times (1/DT\ (\text{first instars})_{i+1} - MF\ (\text{first instars}))$$

Mortality data are not available. Mortality was assumed to increase from 1% per day at 50 g/l salinity to 10% per day at 150 g/l salinity for the larval lifestages. Pupal mortality is not affected by salinity and is set at 0% for all salinities. Temperature does not affect mortality rates in the model.

Biomass Estimates

Biomass represents the total weight of the population standing stock at a single point in time. Units are in dry weight of the population per area (milligrams per square meter [mg/m^2]). Daily biomass for each lifestage is estimated as follows:

$$B = N \times MW$$

where

B is the daily biomass of the lifestage,
N is the population density (ind/m^2) of the lifestage, and
MW is the mean weight of the lifestage.

The mean weight was assumed to be 50% of the weight of a fully developed larval lifestage. Pupal weight is assumed constant throughout this lifestage.

No direct measurements of biomass from the 1991 field data exist for calibration of daily modeled biomass. Daily biomass estimates of first, second, third, and pupal lifestages at elevation 6,375 feet (92 g/l salinity) are shown in Figure L-18. The biomasses of first and second instars were negligible compared to the biomasses of third instars and pupae. Third instars peaked in August at 25 mg/m^2, while pupae peaked later in early September at 35 mg/m^2. Monthly and seasonal average biomass of third instars and pupae are calculated for each lake elevation in the range from 6,350 to 6,420 feet elevation and are shown in Figures L-19A and L-19B. At 6,420 feet elevation (46.5 g/l salinity), the total biomass peaked in early September at about 100 grams per square meter (g/m^2) (monthly average of 110 metric tons [MT]/Lake) for third instars and 65 g/m^2 (monthly average of 80 MT/Lake) for pupae. At 6,350 feet elevation (147 g/l salinity), the total biomass peaked in August at about 8 g/m^2 (monthly average of 12 MT/Lake) for third instars and 17 g/m^2 (monthly average of 25 MT/Lake) for pupae. Biomass of both third instars and pupae reached a maximum at elevations between 6,380 and 6,390 feet of about 40 g/m^2 (monthly average of 170 MT/Lake) at the end of August.

Production Estimates

Production is a measure of how much biomass is produced over a given interval. Units are in dry weight of the population per area per interval (mg/m^2 per day [$mg/m^2/day$]). Production at each lifestage is estimated as the product of the mean weight of the fully developed lifestage and the development rate of that lifestage. The useable production is estimated from third instar production. Daily production of fully developed third instars is calculated using the following equation:

$$P\text{ (third instars)} = N\text{ (third instars)}/DT\text{ (third instars)} \times MFW\text{ (third instars)}$$

where

MFW is the mean full weight.

Daily third instar productivity estimates at a lake level of 6,375 (92 g/l salinity) are graphed in Figure L-20 and show daily productivity peaking at 4 mg/m_2/day at the end of August. At 6,350 feet elevation, peak daily productivity is less than 2 mg/m_2/day, while at 6,420 feet elevation, peak daily productivity reaches 9 mg/m_2/day.

The assessment model further calculates the seasonal total production for each lake level by summarizing daily production values (units are in mg/m^2). Lakewide monthly and seasonal production of third instars (MT/lake/month) are estimated by multiplying the hard substrate production per square meter by the effective habitat area for the range of lake elevations from 6,350 to 6,420 feet (Figure L-21). At low elevations, both high salinity and reduced habitat area cause a minimum seasonal production. At the highest simulated salinity (6,350 feet elevation) the seasonal production was only 150 MT/Lake (47.5 mg/m^2 dry weight) with 49% occurring in August and 19% in September. At intermediate lake elevations of 6,380 to 6,390 feet, the lakewide simulated seasonal production is maximum at approximately 1,350 MT/lake. At higher lake elevations, salinity impacts are reduced, but the effective habitat area is decreased. The total seasonal production at the lowest simulated salinity of 46.5 g/l (6,420 feet elevation) was approximately 710 MT/Lake (227 $mg/m^{2)}$. Most production occurred in August (41%) and September (29%). The majority of production occurs in August for all lake elevations.

The model estimates the proportion of third instar population that remains attached to the substrate as pupae and the fraction that is lost from the substrate to become open water drift or is windrowed ashore. The model specifies separate loss fractions for hard substrate (10%) and soft substrate (90%). The loss fraction increases as the fraction of hard substrate to total substrate decreases. The estimated loss fraction is 60% at 6,350 and 6,420 feet elevation, where the hard substrate constitutes 40% of the total habitat. The estimated loss is 44% at elevation 6,380 feet, where the hard substrate is 58% of the total effective substrate area. Figure L-20 shows the daily production (MT/lake/day) of pupae lost to drift or windrows at elevation 6,375 feet (92 g/l salinity), and Figure L-22 shows the cumulative seasonal production (MT/lake). Cumulative seasonal drift production reaches a maximum of 630 MT/lake at elevations between 6,380 and 6,390 feet. By far, most of these dislodged third instars and pupae are blown ashore as windrows. Some unknown fraction of the generated drift becomes available to the water birds. The open water drift data collected in 1991 by Herbst was used for confirmation of model results.

Primary Productivity Estimates

The benthic algae primary production required for the predicted alkali fly secondary production has not yet been investigated. However, the grazing pressure exerted on benthic algae by alkali fly larvae was estimated by the following equation:

$$GP = P\ (\text{third})/GF$$

where

GP is the daily algal grazing by third instars in g/m^2/day and

GF is the grazing efficiency factor, which for the assessment model is set at 0.2, but which for many ecological systems are as low as 0.1

Although food availability probably influences alkali fly development rates and mean weights, no attempt was made in the model to correlate these. The estimated grazing rate approaches 45 g/m^2/day (dry weight) in the end of August at an elevation of 6,420 feet, a value that is near the upper range of possible aquatic primary production rates.

MODEL CALIBRATION

The 1991 Herbst field data (Herbst 1992) (6,375 feet elevation, 92 g/l salinity) were used to calibrate the daily density patterns for each lifestage. The user can select geometric mean densities from six different sites or an average of all sites and may further choose between soft or hard substrate. The assessment model uses the mean geometric density of all sites on hard substrate. The selected density data were graphed and compared to daily simulated density patterns and minimum and maximum densities of all sites.

The empirical egg density pattern is shown with the observed egg densities in Figure L-23. Figure L-24 shows the simulated first instar density at the 6,375 feet elevation (95 g/l salinity) that occurred in 1991 when the Herbst field data were collected. Both simulated and observed density peaked at 13,000 ind/m^2 during August. Figure L-25 shows the simulated second instar density. Simulated and observed densities reached 15,000 ind/m^2 in August. However, the simulated second instar densities decreased in September and October while the observed second instar density continued to increase dramatically to 35,000 ind/m^2 by October. The reason for these persistent second instars is unknown, and the assessment model cannot simulate this feature of the alkali fly population dynamics.

Figure L-26 shows the simulated and observed third instar densities. Both peaked at approximately 24,000 ind/m^2 in early September. Figure L-27 shows the simulated and observed pupal densities, both of which reached a maximum of 17,000 ind/m^2. The model assumes that all pupae remain attached, so the model densities should be higher than the observed densities. The estimated development time for pupae was increased to equal the third instar development time (30 days at 20°C) to match the observed densities. However, the higher-than-predicted pupal densities might have been due to third instars immigrating from the surrounding soft substrate onto the hard substrate. These discrepancies cannot be resolved with existing information.

The open water drift data (third instars and pupae) collected in 1991 by Herbst were used to obtain reasonable estimates of daily generated drift. Jones & Stokes Associates drift estimates were converted from drift produced per square meter of effective habitat to drift produced per square meter of lake area by multiplying the values with the effective habitat area and dividing with the lake area. Figure L-28 shows modeled drift densities at elevation 6,375 feet (1991 lake level) compared to the arithmetic mean of the drift data. Units are in ind/m^2 and are calculated based on the entire lake. The simulated drift values are approximately tenfold greater than the mean observed drift densities but follow the same seasonal pattern, peaking at about 15 ind/m^2 in the end of August. The observed pattern of drift data generally confirms the seasonal pattern of third instar production.

Assuming that dislodged larvae and pupae endure in the open water for several days would increase the calculated drift values by several fold. However, most of the generated drift is washed ashore rather than swept into the open lake, and some fraction sinks and decays. These unknown daily losses are not incorporated into the model and would greatly reduce the simulated values. The assessment model appears to give a reasonable estimate of drift generation rates if drift persistence and losses are considered and the calibration is considered adequate for alkali fly impact assessment purposes.

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