Example: COVID-2019 data for US (cities and states)

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I am still taking some data from John Hopkins university [1]. However, the format for the US data is different and not consistent. So the database may be updated in the next few days.

As far as I know (at last on 2020-03-04), no data for the recovered cases are (yet) available. The function fit_SEIQRDP is modified to account for this possibility. If the Recovered cases are missing, the recovery rate is set as a constant, i.e. lambda0(2) is no longer used. This should avoid an overparametrization of the model.

[1] https://github.com/CSSEGISandData/COVID-19

Database access

The parameters are here taken as constant except the death rate and recovery rate.

```
clearvars;close all;clc;
[tableConfirmed,tableDeaths,tableRecovered,time] = getDataCOVID_US();
timeRef = time;
```

Case of an entire state

Every city in one state is selected and the cases are added

```
Location = 'Washington'; % Find every cities in Washington state
% Location = 'New York'; % Find every cities in New York state
try
    indC = find(contains(tableConfirmed.Province_State,Location)==1);
    indD = find(contains(tableDeaths.Province_State,Location)==1);
catch exception
    searchLoc = strfind(tableConfirmed.Province_State,Location);
    indC = find(~cellfun(@isempty,searchLoc))  ;

    searchLoc = strfind(tableDeaths.Province_State,Location);
    indD = find(~cellfun(@isempty,searchLoc))   ;
end

% disp(tableConfirmed(indC,1:2))


% Initialisation
Confirmed = 0;
Deaths = 0;
Npop = 0;
```

```
for ii=1:numel(indC)
    Confirmed =  Confirmed + table2array(tableConfirmed(indC(ii),12:end));
end

for ii=1:numel(indD)
    Deaths =  Deaths + table2array(tableDeaths(indD(ii),13:end));
    Npop= Npop + table2array(tableDeaths(indD(ii),12)); % population (dummy number here
end
```

Initial conditions for the fitting

```
% If the number of confirmed Confirmed cases is small, it is difficult to know whether
% the quarantine has been rigorously applied or not. In addition, this
% suggests that the number of infectious is much larger than the number of
% confirmed cases
time = timeRef;
minNum= round(0.05*max(Confirmed)); % 5% of the maximal number of confirmed is used for
Deaths(Confirmed<=minNum)=[];
time(Confirmed<=minNum)= [];
Confirmed(Confirmed<=minNum)=[];

fprintf(['Population = ',num2str(Npop),' \n'])
```

```
Population = 7614893
```

```
% Definition of the first estimates for the parameters
alpha_guess = 0.05;
beta_guess = 0.8; % Infection rate
LT_guess = 5; % latent time in days
Q_guess = 0.5; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.03]; % recovery rate
kappa_guess = [0.07,0.03]; % death rate

guess = [alpha_guess,...
    beta_guess,...
    1/LT_guess,...
    Q_guess,...
    lambda_guess,...
    kappa_guess];

E0 = Confirmed(1); % Initial number of exposed cases. Unknown but unlikely to be zero.
I0 = Confirmed(1); % Initial number of infectious cases. Unknown but unlikely to be zer
Q0 = Confirmed(1)-Deaths(1);
R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number of deat
D0 = Deaths(1);

% Parameter estimation with the lsqcurvefit function[alpha1,beta1,gamma1,delta1,Lambda1
    [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
        fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off');
```

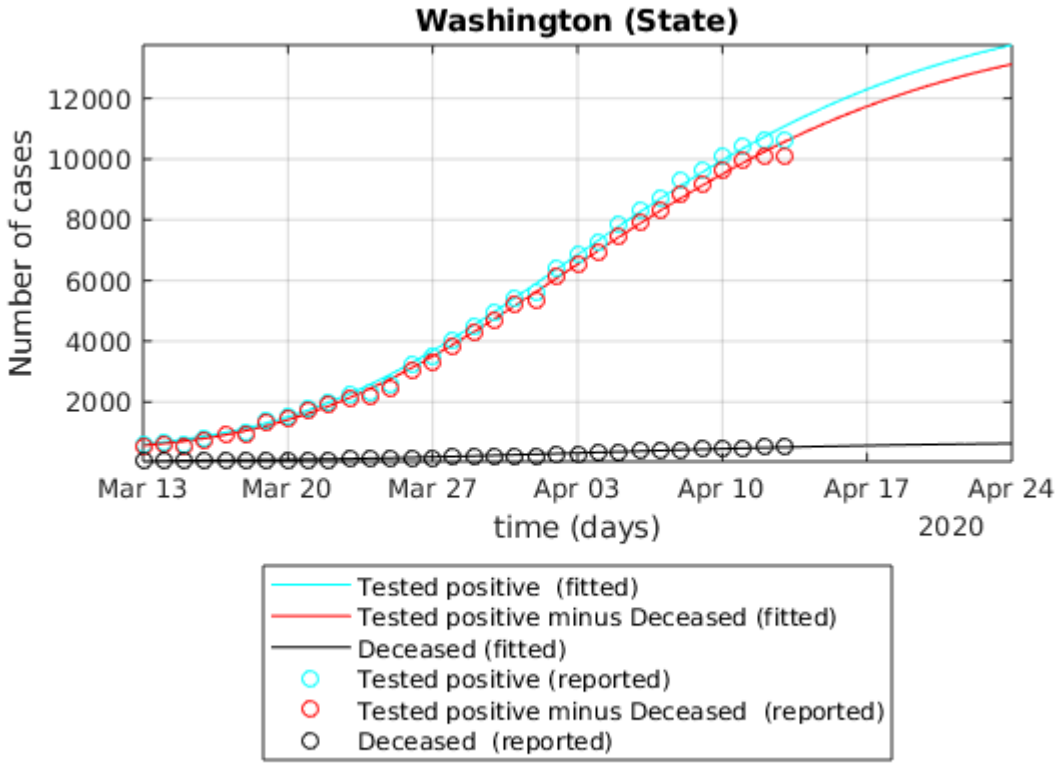
```
Warning:  No data available for "Recovered"
```

Simulate the epidemy outbreak based on the fitted parameters

```
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(10)));
N = numel(time1);
t = [0:N-1].*dt;
[S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,...
    gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0,t);
```

Comparison of the fitted and real data

```
figure
semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
hold on
semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
% ylim([0,1.1*Npop])
ylabel('Number of cases')
xlabel('time (days)')
leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',...
    'Deceased (fitted)',...
    'Tested positive (reported)',...
    'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
axis tight
title([Location,' (State)'])
set(gca,'yscale','lin')
```



Example of a single city

```
time = timeRef;

fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

```
Most recent update: 13-Apr-2020
```

```
Location = 'New York City, New York, US';


try
    indC = find(contains(tableConfirmed.Combined_Key,Location)==1);
    indD = find(contains(tableDeaths.Combined_Key,Location)==1);
catch exception
    searchLoc = strfind(tableConfirmed.Combined_Key,Location);
    indC = find(~cellfun(@isempty,searchLoc))  ;

    searchLoc = strfind(tableDeaths.Combined_Key,Location);
    indD = find(~cellfun(@isempty,searchLoc))   ;
end

disp(tableConfirmed(indC,11));
```

```
    Combined_Key
```

```
"New York City, New York, US"
```

```
indC = indC(1);
indD  = indD(1);

Deaths = table2array(tableDeaths(indD,13:end));
Confirmed = table2array(tableConfirmed(indC,12:end));
Npop= table2array(tableDeaths(indD,12)); % population (dummy number here)
```

Initial conditions for the fitting

```
% If the number of confirmed Confirmed cases is small, it is difficult to know whether
% the quarantine has been rigorously applied or not. In addition, this
% suggests that the number of infectious is much larger than the number of
% confirmed cases
minNum= round(0.05*max(Confirmed)); % 5% of the maximal number of confirmed is used for
Deaths(Confirmed<=minNum)=[];
time(Confirmed<=minNum)= [];
Confirmed(Confirmed<=minNum)=[];

fprintf(['Population = ',num2str(Npop),' \n'])
```

```
Population = 5803210
```

```
% Definition of the first estimates for the parameters
alpha_guess = 0.05;
beta_guess = 0.8; % Infection rate
LT_guess = 5; % latent time in days
Q_guess = 0.5; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.03]; % recovery rate
kappa_guess = [0.07,0.03]; % death rate

guess = [alpha_guess,...
    beta_guess,...
    1/LT_guess,...
    Q_guess,...
    lambda_guess,...
    kappa_guess];

E0 = Confirmed(1); % Initial number of exposed cases. Unknown but unlikely to be zero.
I0 = Confirmed(1); % Initial number of infectious cases. Unknown but unlikely to be zer
Q0 = Confirmed(1)-Deaths(1);
R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number of deat
D0 = Deaths(1);

% Parameter estimation with the lsqcurvefit function[alpha1,beta1,gamma1,delta1,Lambda1
    [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
        fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off');
```

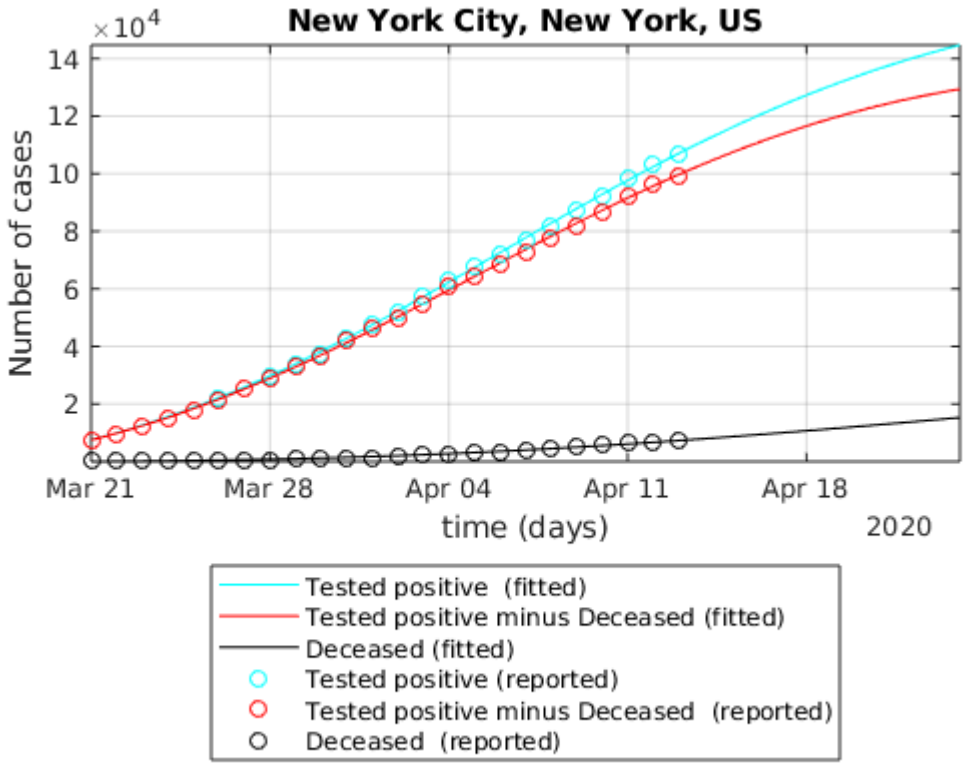
```
Warning:  No data available for "Recovered"
```

Simulate the epidemy outbreak based on the fitted parameters

```
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(10)));
N = numel(time1);
t = [0:N-1].*dt;
[S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,...
    gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0,t);
```

Comparison of the fitted and real data

```
figure
semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
hold on
semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
% ylim([0,1.1*Npop])
ylabel('Number of cases')
xlabel('time (days)')
leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',...
    'Deceased (fitted)',...
    'Tested positive (reported)',...
    'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
axis tight
title([Location])
set(gca,'yscale','lin')
```



Case of multiple cities

The fitting is more challenging and uncertainties are indCreased because the number of recovered is unknown. In particular, the sensitivity on the initial guess is quite high. I have limited trust in the results provided by fit_SEIQRDP.

```
time = timeRef;
fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

```
Most recent update: 13-Apr-2020
```

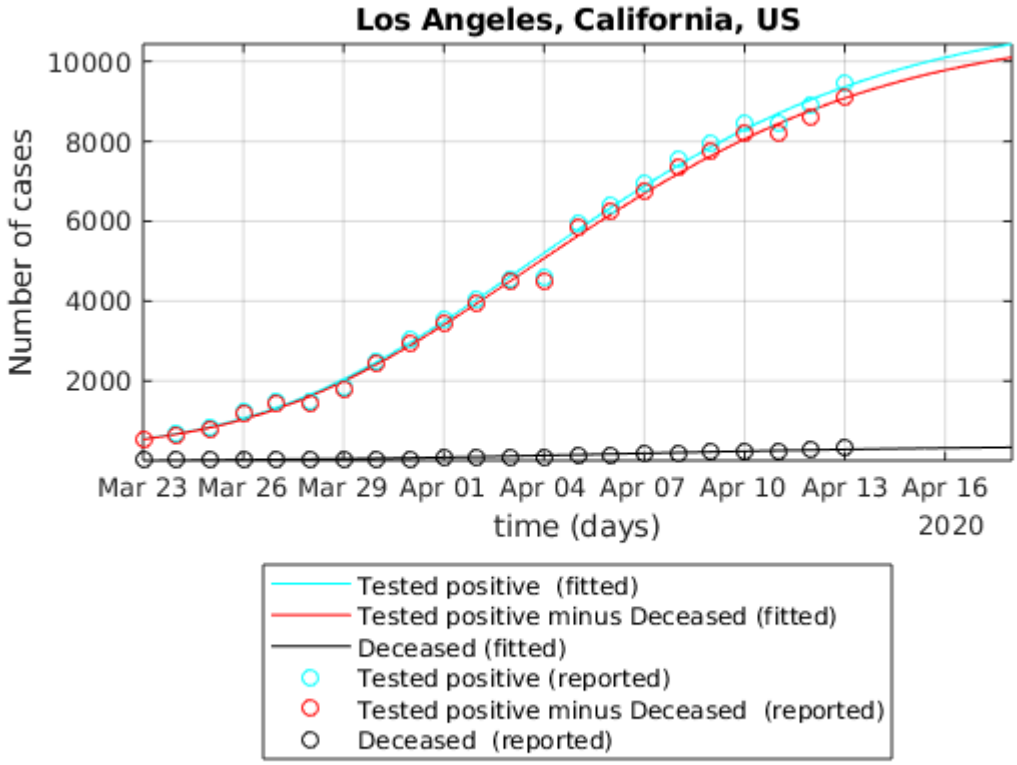
```
for ii = 2:numel(tableConfirmed.Combined_Key)

    Location = tableConfirmed.Combined_Key(ii);

    indC = find(strcmpi(tableConfirmed.Combined_Key,Location)==1);
    indD = find(strcmpi(tableDeaths.Combined_Key,Location)==1);

    Deaths = table2array(tableDeaths(indD,13:end));
    Confirmed = table2array(tableConfirmed(indC,12:end));
    Npop= table2array(tableDeaths(indD,12)); % p

    if Npop == 0
%         warning('Unreal population found. A dummy variable is used instead')
        Npop = 1e6; % dummy population is used instead
    end
```

```
    time = timeRef;
    minNum= round(0.05*max(Confirmed)); % 5% of the maximal number of confirmed is used
    Deaths(Confirmed<=minNum)=[];
    time(Confirmed<=minNum)= [];
    Confirmed(Confirmed<=minNum)=[];


    if minNum>300 && numel(Confirmed) >10 % more than 10 days of good data
        disp(tableConfirmed(indC,11));
        fprintf(['Population = ',num2str(Npop),' \n'])
        % Definition of the first estimates for the parameters
        alpha_guess = 0.1;
        beta_guess = 0.8; % Infection rate
        LT_guess = 5; % latent time in days
        Q_guess = 0.5; % rate at which infectious people enter in quarantine
        lambda_guess = [0.08,0]; % recovery rate
        kappa_guess = [0.07,0.03]; % death rate

        guess = [alpha_guess,...
            beta_guess,...
            1/LT_guess,...
            Q_guess,...
            lambda_guess,...
            kappa_guess];

        E0 = Confirmed(1); % Initial number of exposed cases. Unknown but unlikely to b
        I0 = Confirmed(1); % Initial number of infectious cases. Unknown but unlikely t
        Q0 = Confirmed(1)-Deaths(1);
        R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number
        D0 = Deaths(1);

        % Parameter estimation with the lsqcurvefit function
        [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1] = ...
            fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off

        dt = 1/24; % time step
        time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(4)));
        N = numel(time1);
        t = [0:N-1].*dt;
        [S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,


        figure
        semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
        hold on
        semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
        % ylim([0,1.1*Npop])
        ylabel('Number of cases')
        xlabel('time (days)')
        leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',...
            'Deceased (fitted)',...
            'Tested positive (reported)',...
            'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
        legend(leg{:},'location','southoutside')
```

```
        set(gcf,'color','w')
        grid on
        axis tight
        title([Location])
        set(gca,'yscale','lin')

        pause(1)
    end
end
```

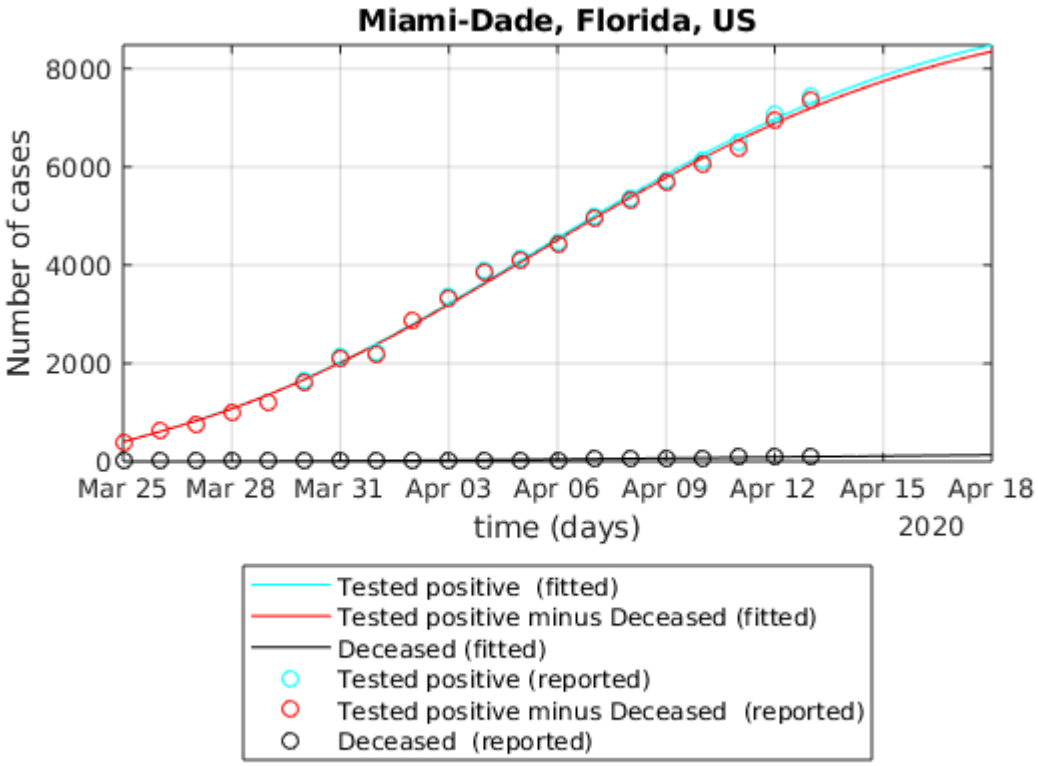
Combined_Key

"Los Angeles, California, US"
Population = 10039107
Warning: No data available for "Recovered"



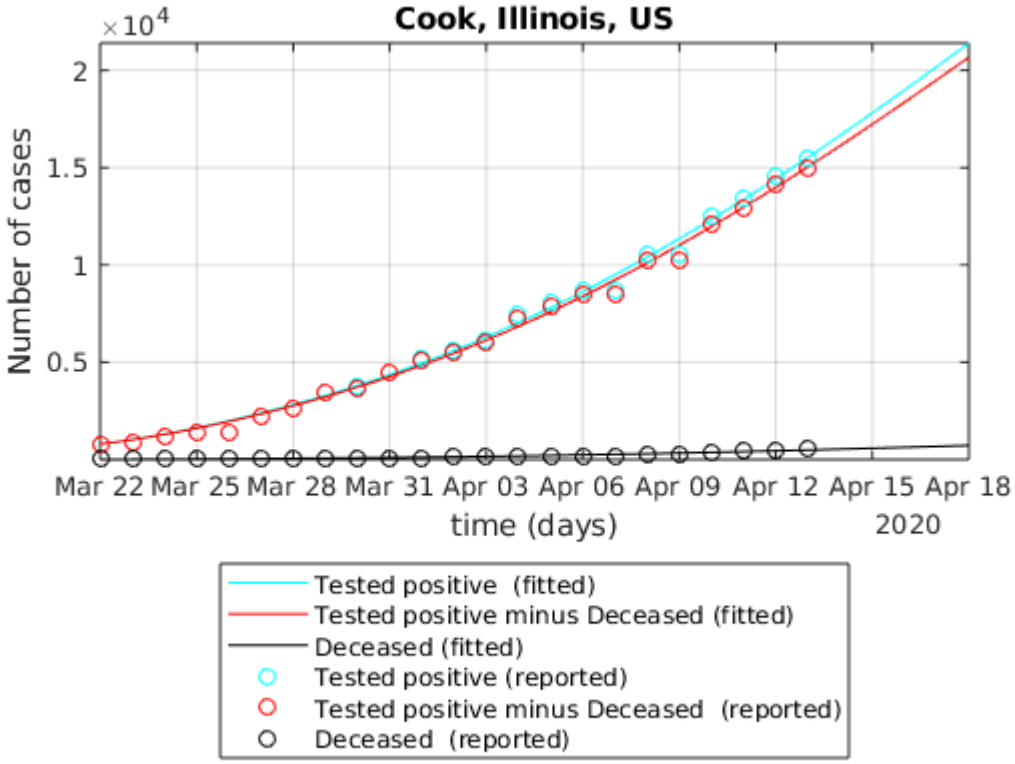
Combined_Key

"Miami-Dade, Florida, US"
Population = 2716940
Warning: No data available for "Recovered"



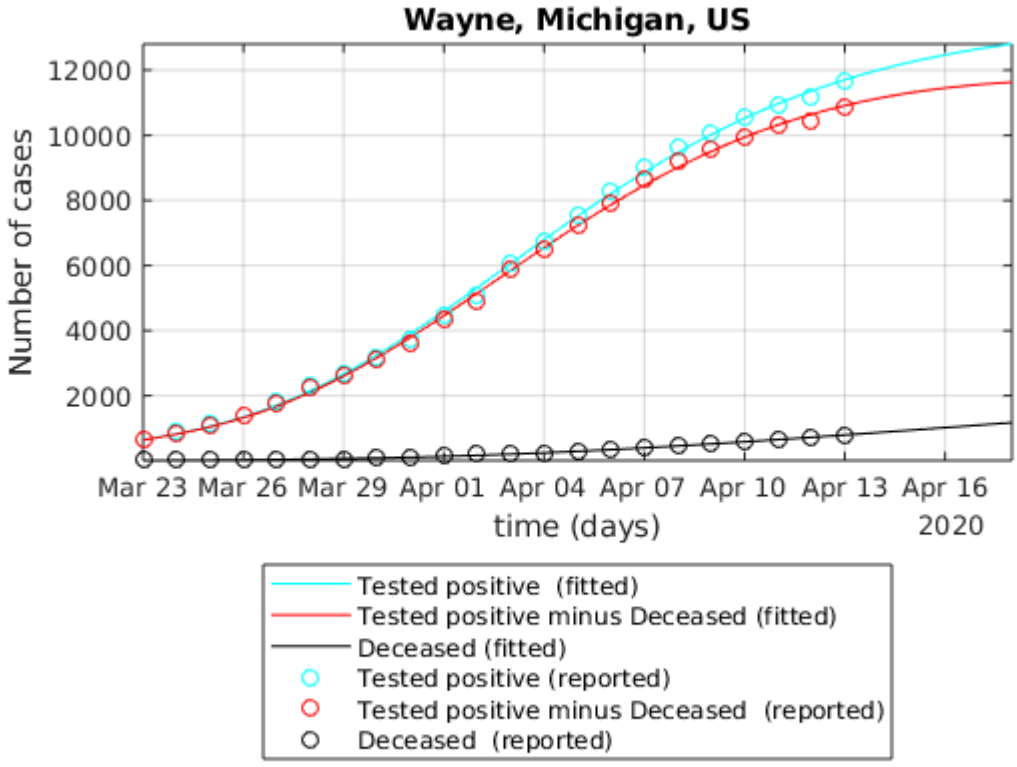
Combined_Key

"Cook, Illinois, US"
Population = 5150233
Warning: No data available for "Recovered"



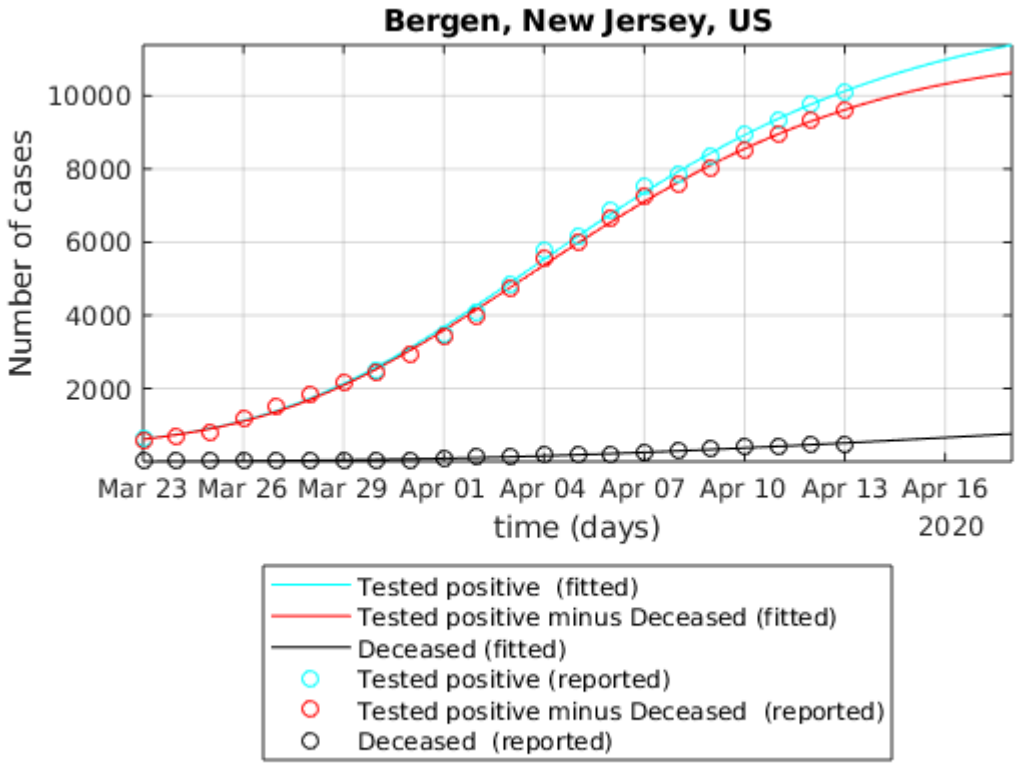
Combined_Key

"Wayne, Michigan, US"
Population = 1749343
Warning: No data available for "Recovered"



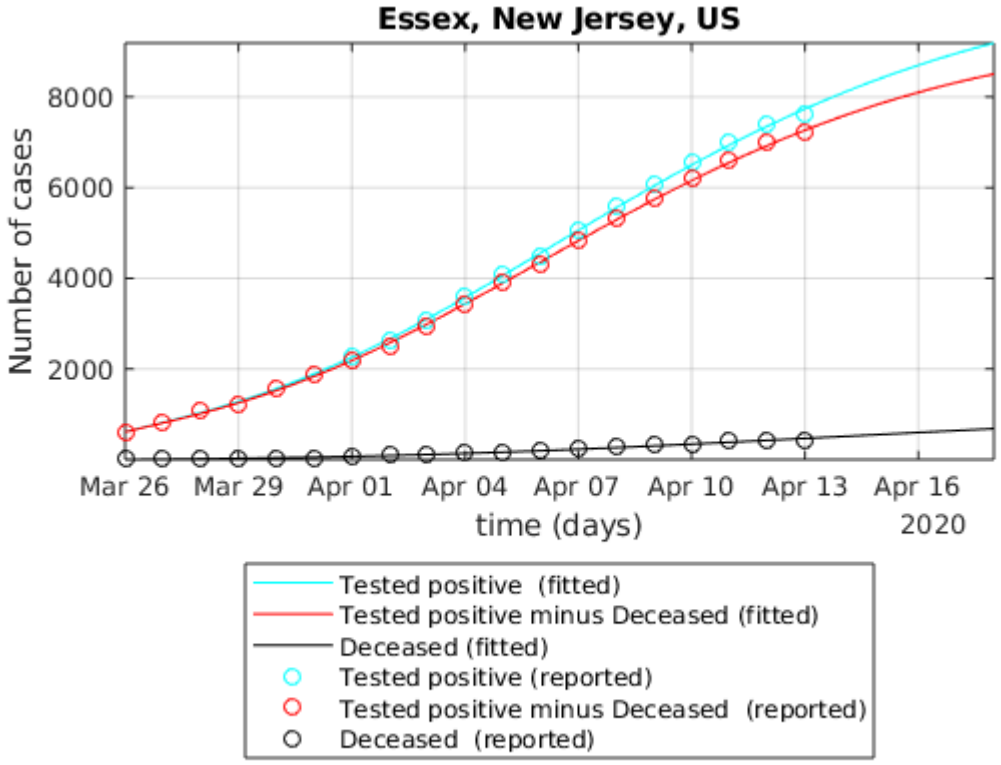
Combined_Key

"Bergen, New Jersey, US"
Population = 932202
Warning: No data available for "Recovered"

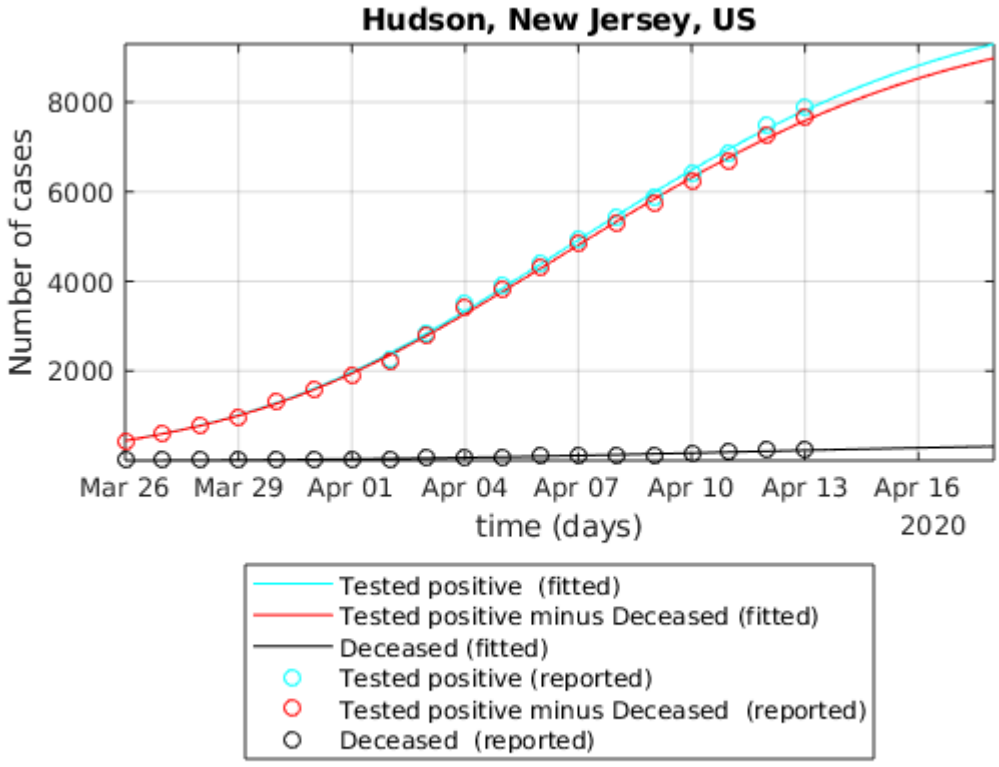


Combined_Key

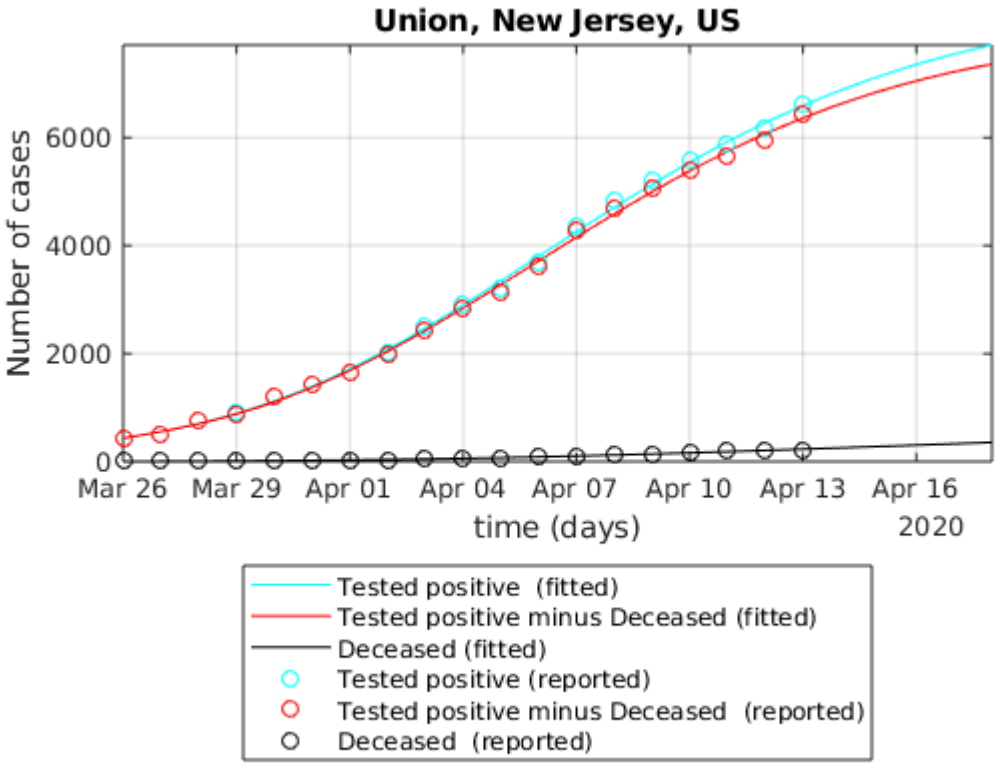
"Essex, New Jersey, US"
Population = 798975
Warning: No data available for "Recovered"



```
Combined_Key
_____________________________

    "Hudson, New Jersey, US"
Population = 672391
Warning:  No data available for "Recovered"
```

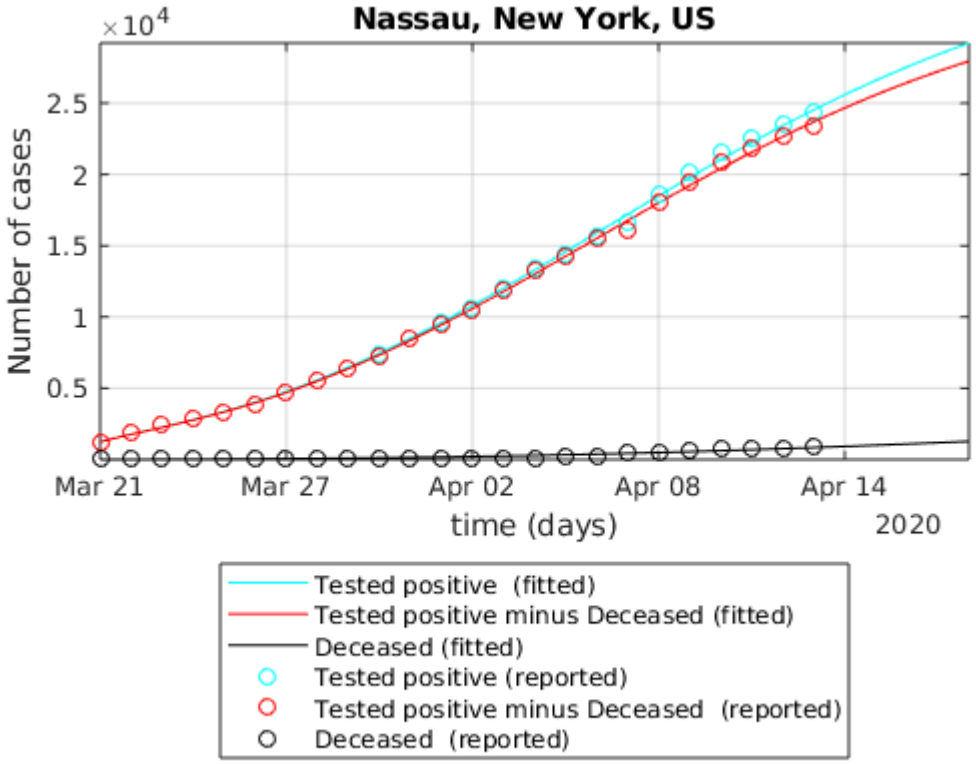



```
Combined_Key
_____________________________

    "Union, New Jersey, US"
Population = 556341
Warning:  No data available for "Recovered"
```



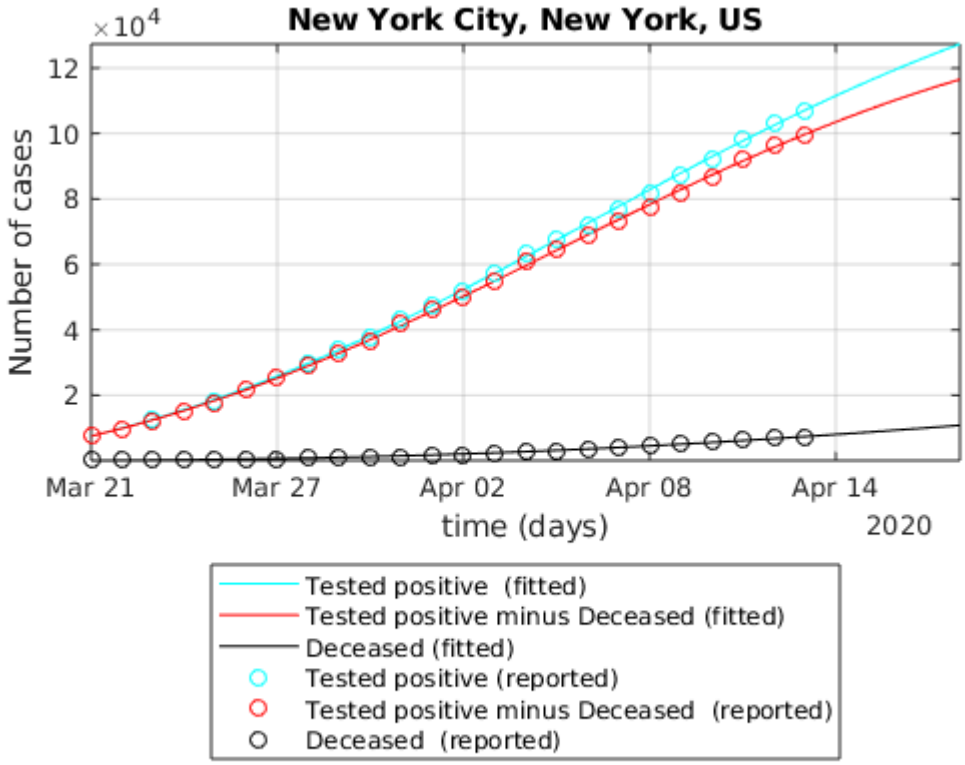
Combined_Key

```
    "Nassau, New York, US"
Population = 1356924
Warning:  No data available for "Recovered"
```



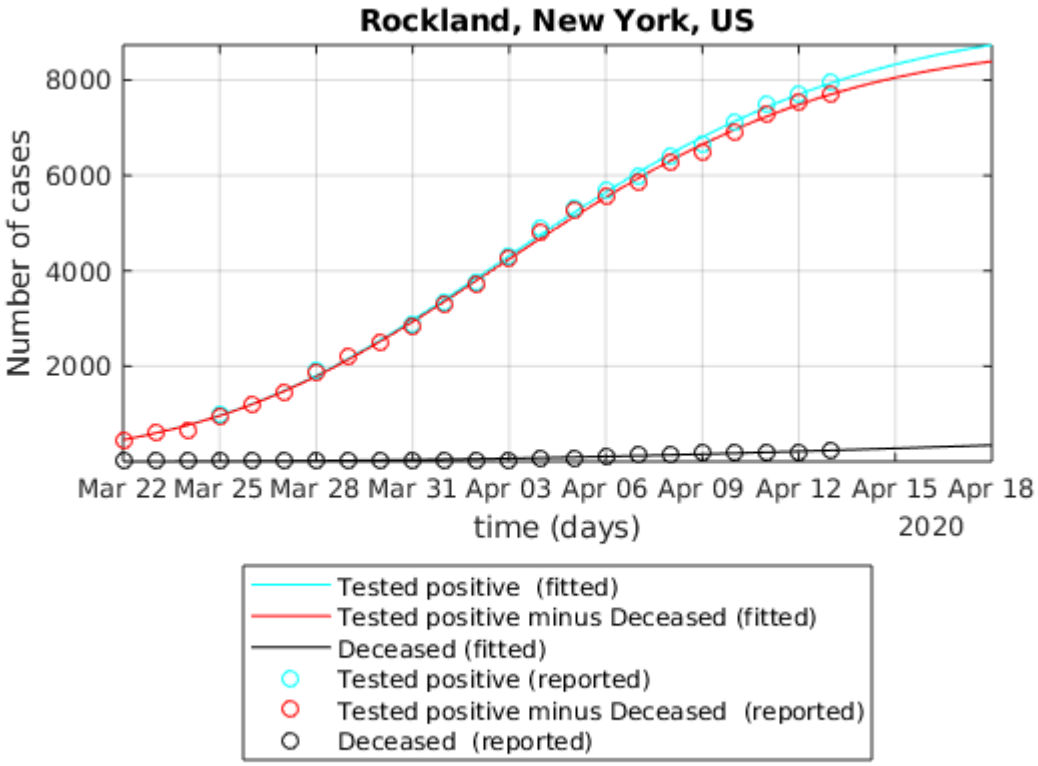
Combined_Key

"New York City, New York, US"
Population = 5803210
Warning: No data available for "Recovered"



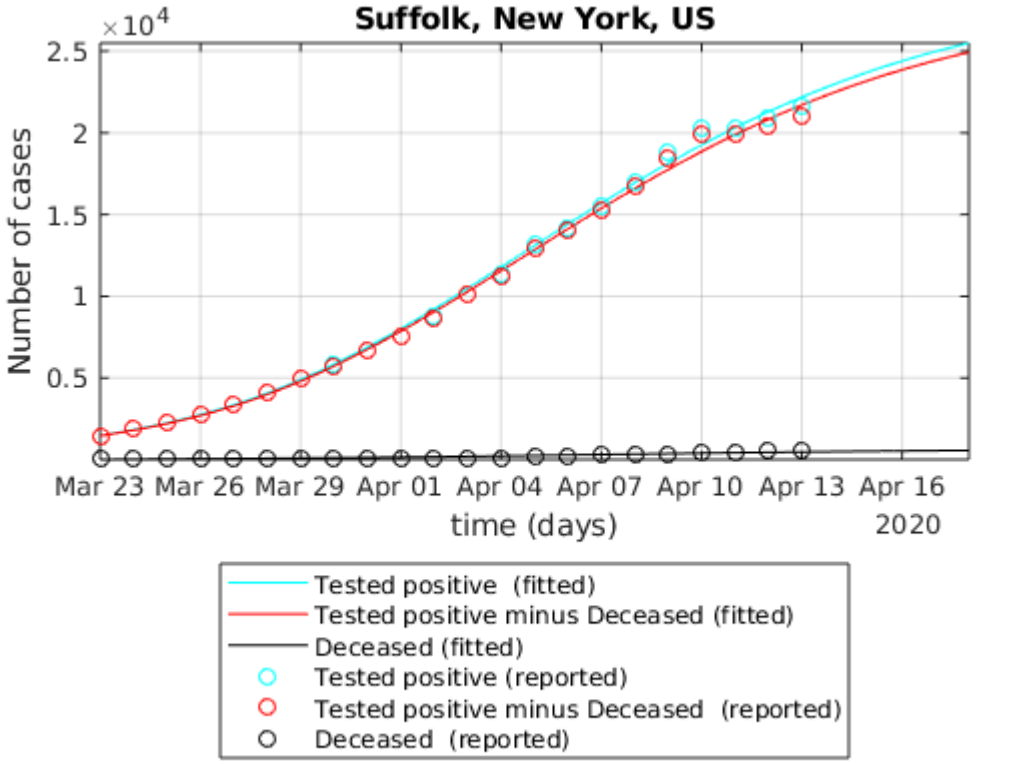
Combined_Key

"Rockland, New York, US"
Population = 325789
Warning: No data available for "Recovered"



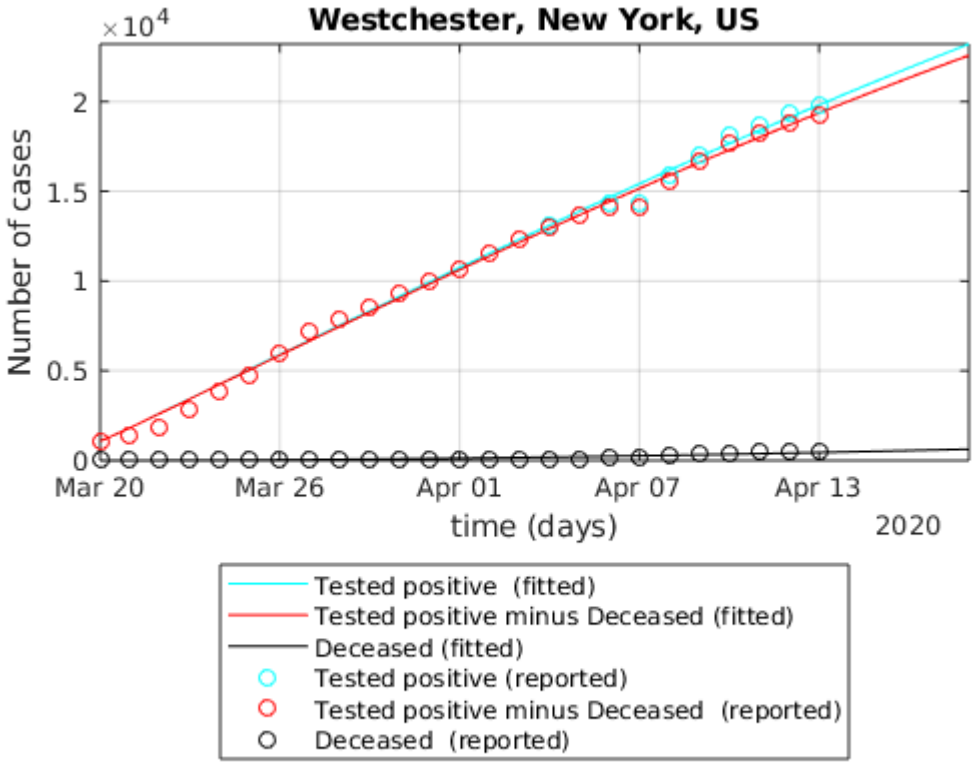
Combined_Key

"Suffolk, New York, US"
Population = 1476601
Warning: No data available for "Recovered"



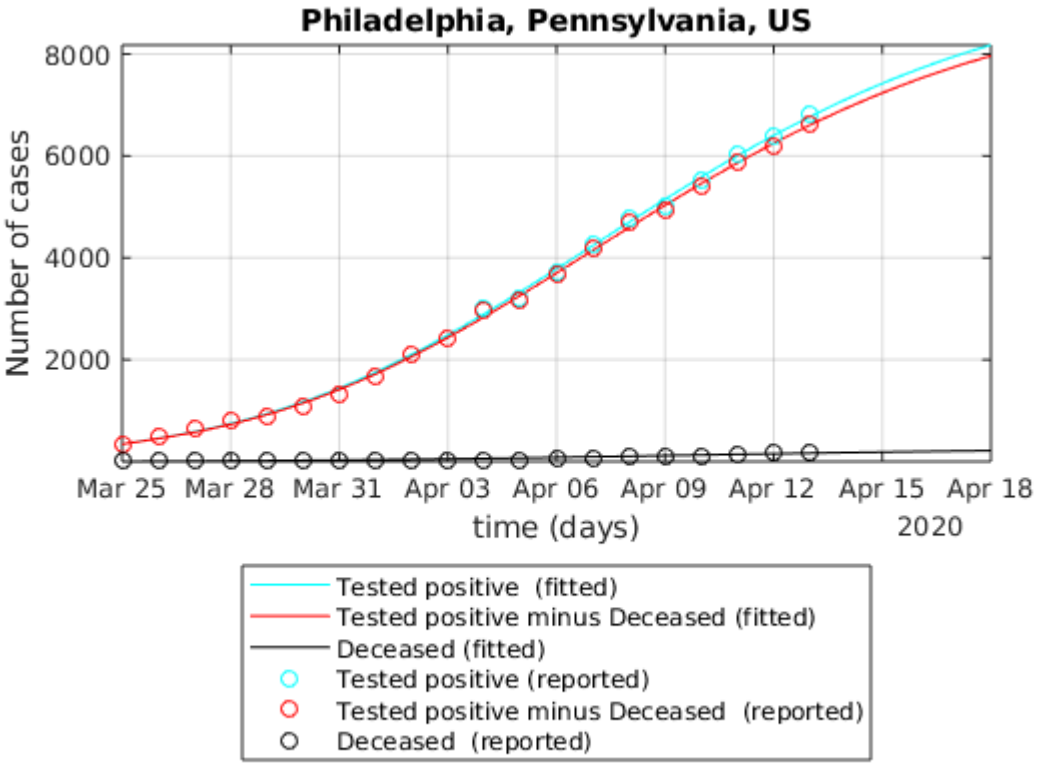
Combined_Key

"Westchester, New York, US"
Population = 967506
Warning: No data available for "Recovered"



Combined_Key

"Philadelphia, Pennsylvania, US"
Population = 1584064
Warning: No data available for "Recovered"


Philadelphia, Pennsylvania, US
Number of cases
8000
6000
4000
2000
Mar 25
Mar 28
Mar 31
Apr 03
Apr 06
Apr 09
Apr 12
Apr 15
Apr 18
time (days)
2020
Tested positive (fitted)
Tested positive minus Deceased (fitted)
Deceased (fitted)
Tested positive (reported)
Tested positive minus Deceased (reported)
Deceased (reported)