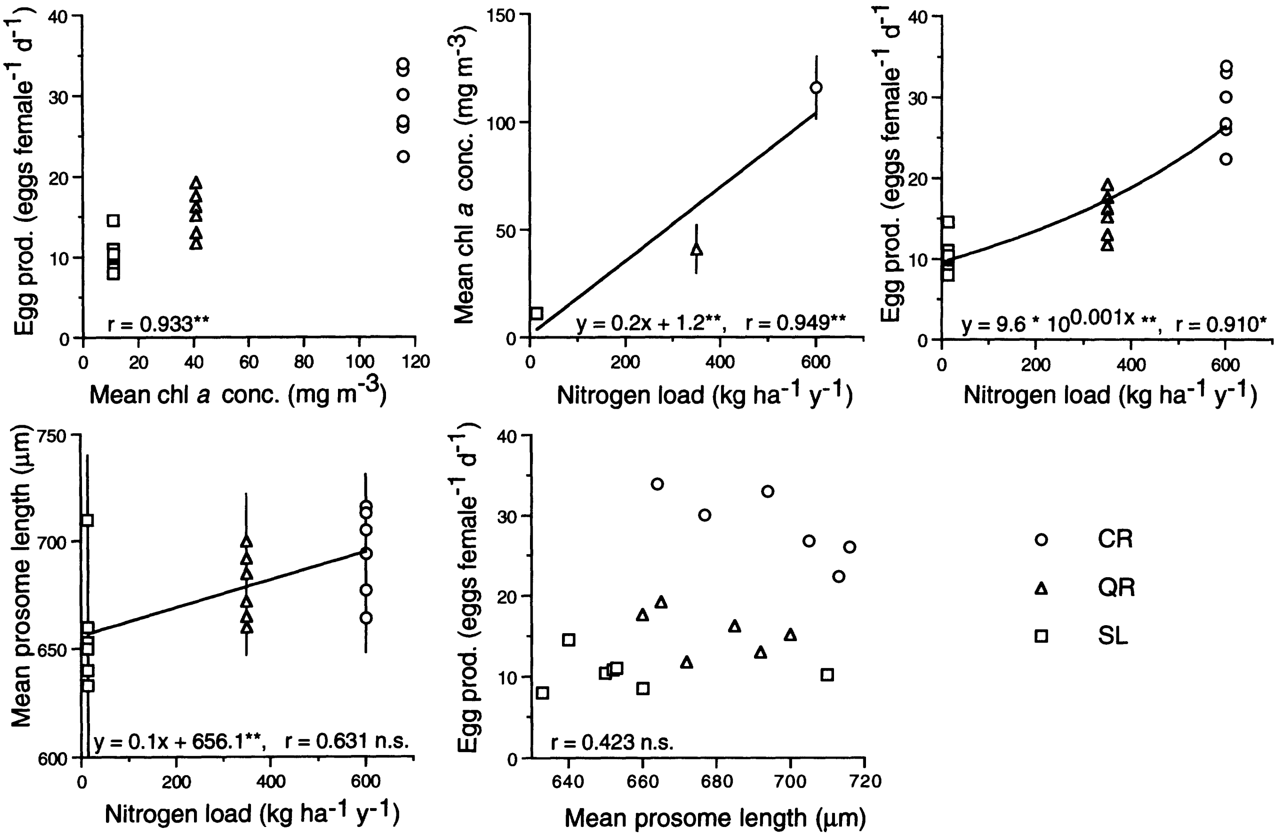

Figure 1. *Top left: Egg production rate (eggs female^{-1} day^{-1})* versus *mean chlorophyll concentration (mg m^{-3}). Top middle: Mean chlorophyll concentration* versus *land-derived nitrogen load (kg ha^{-1} y^{-1}). The lines represent standard error. Nitrogen loads obtained from Valiela* et al. *(2). Top right: Egg production rate* versus *land-derived nitrogen load. Bottom left: Mean prosome length* versus *nitrogen load. The lines represent standard error. Bottom right: Egg production rate* versus *mean prosome length of females (µm). One asterisk indicates significance of <0.05 and two asterisks indicate significance of <0.01.*

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Long-Term Effect of Municipal Water Use on the Water Budget of the Ipswich River Basin

Susannah Canfield[1], Luc Claessens, Charles Hopkinson Jr., Edward Rastetter, and Joseph Vallino
(The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543)

The Ipswich River watershed has served as a public water supply to suburban communities north of Boston since the late 1800s. Population growth and land-use changes have affected the hydrology of the watershed by increasing the amount of water pumped from the basin and altering the land cover—a problem that is prevalent nationwide (1). In recent years, the river has suffered

[1] Bates College, Lewiston, Maine 04240.

from low flows in the summer (2). Low streamflow can be detrimental to the ecosystem of the river, the surrounding wetlands, and the estuary into which the river drains (1). The purpose of this study was to examine the effect of municipal water use on the overall water budget of the Ipswich River basin.

Monthly water budgets were constructed for the period 1931–1989 as: $\Delta S = P - ET - R - D$, where P is precipitation; ET is evapotranspiration; R is streamflow; D is net diversions, including drinking water and wastewater; and ΔS is change in storage. Precipitation data were obtained from observations of the National Weather Service (NWS) and cooperative network. Observations from NWS first-order weather stations were used to calculate evapotranspiration using a mathematical model (3). Streamflow data were obtained from the U.S. Geological Survey. Data on monthly water pumpage and wastewater systems were collected from individual town water departments, the Department of Environmental Protection, the Massachusetts Area Planning Council, and the Massachusetts Water Resources Authority. Public drinking water was divided into public water supply from within and from outside the watershed based on the locations of pumping stations relative to the boundary of the Ipswich River basin. Using population data and the relative distribution of urban land use for each town, we separated the total public water supply into water delivered inside and outside the basin. To account for lawn and plant watering, an irrigation coefficient was calculated for the summer months by considering the difference between summer and winter pumpage. Finally, the remaining water, for commercial and household use, was divided into wastewater exported out of the basin *via* sewer systems and wastewater retained in the watershed by on-site septic disposal. Sewered water was assumed to have a 65% infiltration component from groundwater (4). Linear regression analyses were performed to examine time-dependent trends in annual, monthly, and seasonal data.

On a long-term annual scale (Fig. 1a), precipitation, streamflow, and evapotranspiration are highly variable but do not display any significant time-dependent trends. Only diversions have increased significantly over time ($r = 0.96$, $P < 0.001$) and currently represent 15%–20% of streamflow. One would expect that with a significant increase in diversions, streamflow would decrease significantly. It is plausible, however, that changes in land use have masked the effect of diversions on streamflow and the overall water budget; for example, the conversion of forested area to impervious land cover could lead to an increase in streamflow and a decrease in evapotranspiration (5). Our analysis of the main diversion components shows an increase in water drawn from within and outside the basin, tripling over the 59-year period (Fig. 1b). Water supply from outside the basin constitutes 30% of the total supply; of this total water supply, 71% is delivered outside the watershed. The septic wastewater component levels off after 1966, when sewer systems became more prevalent.

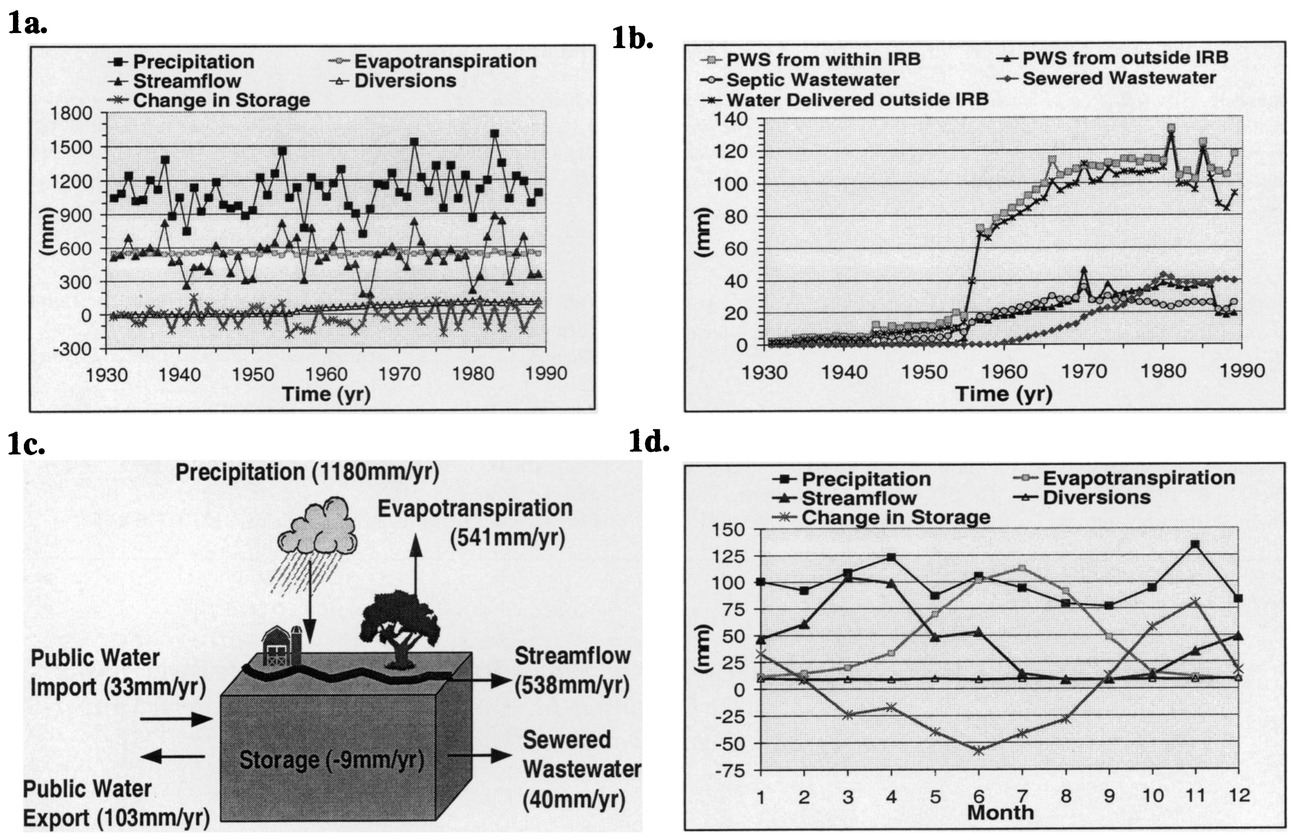

Figure 1. *(a) 1931–1989 annual time series of the main components of the water budget, with only diversions increasing significantly. (b) 1931–1989 annual time series of the components of diversions, including public water supply (PWS) from within and from outside the Ipswich River basin (IRB), water delivered outside the basin, septic and sewered wastewater, including infiltration. (c) Main components of the Ipswich River basin water budget, including 1979–1988 annual averages. (d) 1979–1988 average monthly time series of the main components of the water budget.*

In the 1979–1988 water budget (Fig. 1c), which is representative of current conditions, evapotranspiration (541 mm/y) and streamflow (538 mm/y) each account for about 45% of precipitation (1180 mm/y). Diversions leaving the basin (143 mm/y) are greater than diversions entering the basin (33 mm/y). The change in storage (−9 mm/y) is small. However, in this study, we ignored the absolute value of the storage component because it is highly dependent on the evapotranspiration estimate, which is the least accurate component of any large-scale water budget; only the temporal variation is considered. During the summer months (Fig. 1d), the change in storage is most negative, due to increasing evapotranspiration, and it is coincident with decreasing rainfall and streamflow. Diversions remain relatively constant throughout the year, with high groundwater pumping during the summer balanced by surface water withdrawals into reservoirs during the rest of the year. The effect of diversions should be most apparent during the summer months because streamflow is lowest at this time.

With increasing water demands, diversions have become a major component of the water budget—they currently represent 15%–20% of the streamflow. Our analyses of the water budget did not reveal any significant long-term trend in change in storage or in streamflow. This suggests that to understand the impact of diversions on the system we ought to reduce the time step (to daily or hourly) to examine changes in streamflow; focus the study area on the upper Ipswich basin where low flows occur and the river dries up most frequently; and look at different indices of hydrological change, such as the number of days of low flow and groundwater levels. Low streamflow is detrimental not only to the river ecosystems, but also to the downstream estuary, where alterations in salinity during the summer months could increase the stress on estuarine communities, a topic that requires further research.

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Population Size and Summer Home Range of the Green Crab, *Carcinus maenas*, in Salt Marsh Tidal Creeks

Talia Young (Swarthmore College, Swarthmore, Pennsylvania 19081), Sharon Komarow[1], *Linda Deegan*[2] *and Robert Garritt*[2]

The green crab, *Carcinus maenas,* is native to the Atlantic coast of Europe. First reported in the western Atlantic in 1817, it is abundant today in salt marshes and on rocky shores from Nova Scotia to Virginia. As a predator, it has been linked to the sharp decline of the New England soft-shell clam (*Mya arenaria*) industry in the 1940s (1). Since the crab was first found in San Francisco Bay in 1989, scientists and fishers have been anxiously monitoring its movement northward and its effects on the ecosystem (2). Despite interest in the extension of the species' geographic distribution, little work has been conducted on the home range of individual crabs. We examined the population size and summer home range of green crabs in a New England salt marsh tidal creek.

We conducted a mark-recapture experiment in a branched primary tidal creek off of the Rowley River in the Plum Island Sound Estuary in northeastern Massachusetts. The upper 200 m of the creek has about 7274 m^3 of volume and about 7128 m^2 of creek bed area. Water temperature (16°–25°C) and salinity (28‰–31‰) in the creek were typical of New England salt marshes in late spring and summer. From 29 June to 6 August 1999, crawfish traps (20 × 30 × 45 cm with 1.3-cm mesh and 8-cm opening) baited with tuna fish or dog food soaked in fish oil were laid along both branches and downstream of the confluence at seven sites 100 m apart. From 29 June to 30 July, each trapped crab measuring 40 mm or more was marked either with colored oil-based marker paint on the carapace or with a plastic loop behind the claws. The carapace width (in millimeters), sex (male or female), and carapace color (red or green) of each crab were also noted. Crabs trapped at each of the seven sites were marked with a distinct color scheme and then released at the same site. Marked crabs that were recaptured were marked a second time with the color scheme corresponding to their recapture location. Crabs trapped from 3 to 6 August were counted and removed from the creek. We used the Lincoln index and the Schnabel method to estimate population size (3). We also conducted two catch-per-unit-effort collections in five other similar-sized primary tidal creeks off of the Rowley River (Sand Creek, Shad Creek, West Creek, Club Head Creek, and Nelson Island Creek) by deploying traps from high tide to low tide (~6 h).

We estimated the population of green crabs in the study creek to be 30,000–40,000 individuals (~5 crabs per m^2) (Table I). Recapture rate of marked crabs was between 5% and 11%. The average number of crabs caught over a 6-h period did not differ significantly between the study creek and the other five creeks

[1] Earth Systems Program, Stanford University, Stanford, California 94035.

[2] Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543.