(1) $a_2a_4 = a_5 \Rightarrow a_1^2q^4 = a_1q^4 \Rightarrow a_1 = 1$

$a_3 - 4a_2 + 4a_1 = 0 \Rightarrow q^2 - 4q + 4 = 0 \Rightarrow q = 2$

故 $\{a_n\} = 2^{n-1}$ 是 "M-数列"

(2) ① $S_n = \frac{1}{\frac{2}{b_n} - \frac{2}{b_{n+1}}} = \frac{b_nb_{n+1}}{2(b_{n+1}-b_n)}$

$S_{n+1} = \frac{b_{n+1}b_{n+2}}{2(b_{n+2}-b_{n+1})}$

$b_{n+1} = S_{n+1} - S_n$

$= b_{n+1}[\dfrac{b_{n+2}(b_{n+1}-b_n) - b_n(b_{n+2}-b_{n+1})}{2(b_{n+2}-b_{n+1})(b_{n+1}-b_n)}]$

$2(b_{n+2}b_{n+1} - b_{n+2}b_n - b_{n+1}^2 + b_nb_{n+1})$

$= (b_{n+2}b_{n+1} - 2b_nb_{n+2} + b_nb_{n+1})$

$b_{n+2}b_{n+1} - 2b_{n+1}^2 + b_nb_{n+1} = 0$

$b_{n+1}(b_{n+2} - 2b_{n+1} + b_n) = 0$

故 $\{b_n\}$ 为等差数列

$n = 1$ 时,$1 = 2 - \frac{2}{b_2} \Rightarrow b_2 = 2$

故 $\{b_n\} = n$

② 设 $\{c_n\} = q^{n-1}$ 由题意: $c_k \leqslant b_k \leqslant c_{k+1}$

$q^{k-1} \leqslant k \leqslant q^k$

$(k-1)\ln q \leqslant \ln k \leqslant k\ln q$

$\dfrac{\ln k}{k} \leqslant \ln q \leqslant \dfrac{\ln k}{k-1}$

设 $f(x) = \frac{\ln x}{x}$ 则 $f'(x) = \frac{1-\ln x}{x^2}$

$f'(x) = 0$ 时 $x = e$

$x < e$ 时 $f(x)$ 单调递增 $x > e$ 时 $f(x)$ 单调递减

故 $f(x)$ 在 $x = e$ 处取得最大值。

若 x 取整数, $f(2) = \frac{\ln 2}{2} = \ln(\sqrt[6]{8}), f(3) = \frac{\ln 3}{3} = \ln(\sqrt[6]{9})$

故 $f(x)$ 在 $x = 3$ 处取得最大值

即只需 $q \geqslant \sqrt[3]{3}, f(x) \leqslant \ln q$ 恒成立

设 $g(x) = \frac{\ln x}{x-1}, f'(x) = \frac{1-\frac{1}{x}-\ln x}{(x-1)^2}$

记 $h(x) = 1 - \frac{1}{x} - \ln x, h'(x) = \frac{1}{x^2} - \frac{1}{x}$

$x > 0$ 时,$x = 1$ 时取得最大值 $h(1) = 0$

故 $g'(x) \leqslant 0, g(x)$ 单调递减

$k \leqslant 3$ 时 $g(x)$ 递减 , $f(x)$ 递增

只需 $\sqrt[3]{3} \leqslant q \leqslant \sqrt{3}$,

便有 $f(x) \leqslant f(3) \leqslant \ln q \leqslant g(3) \leqslant g(x)$
$k > 3$ 后 $g(x)$ 递减, 当 $g(x) < \ln \sqrt[3]{3}$ 时，不等式在 $k = 3$ 处不成立
而 $g(5) = \ln(\sqrt[4]{5}) = \ln(\sqrt[12]{125})$
$g(6) = \ln(\sqrt[5]{6}) = \ln(\sqrt[15]{216})$
而 $\sqrt[3]{3} = \sqrt[12]{81} = \sqrt[15]{243}$
故 k 最大为 5, 即 $m = 5$