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Growth models of gilthead sea bream (*Sparus aurata* L.) for aquaculture: A review

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ABSTRACT

Gilthead sea bream (*Sparus aurata* L.) is a fish commonly cultivated in the Mediterranean sea in marine cages and recirculating aquaculture systems. Managing such growing systems, requires a growth model to describe the response of the fish to their environment. The dominant predictors of growth, assuming adequate water quality, are fish size, M, water temperature, T, and feed ration, F. Over the past 30 years many experimental studies with gilthead sea bream have been conducted, each providing partial information regarding the growth function $G\{M, T, F, \ldots\}$.

In this study an attempt is made to critically review the available information from an aquacultural management point of view, selecting simple sub-models which preserve the essentials of the various processes. It seems that for the practical range of application for gilthead sea bream (first two years of life and sub-optimal (<25 °C) temperatures), growth is exponentially dependent on body size and linearly dependent on both temperature and feed ration. A representative growth model with these features, calibrated with the available data, is proposed. Unlike the more sophisticated, two-term bioenergetic models, the suggested model consists of just one multiplicative term. Final calibration of the growth model for any particular facility may be achieved by on-line adaptation of a few of the model parameters.

Contents

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Nomenclature

Main symbols (first appear in Eq. . . .) Units are those used most often

A	feed equivalent of fish body mass (Eq. (33)) g[BM]/g[feed]
A	anabolism (Eq. (3)) g[BM]/(fish day)
a	coefficient of exponential growth (Eq. (27)) $\left(\text{g[BM]/fish}\right)^{1-\chi}$/day
b	growth temperature coefficient (Eq. (27)) 1/°C
C	Feed conversion ratio (FCR) (Eq. (37)) g[feed]/g[BM]
C	catabolism (Eq. (3)) g[BM]/(fish day)
E	environment vector (Eq. (1)) **
E	anabolic rate of growth (Eq. (10)) cm/day
F	feed ration (Eq. (2)) g[feed]/(fish day)
G	growth function (Eq. (2)) g[BM]/(fish day)
G	growth function vector (Eq. (1)) **
g	growth response (correction) factor (Eq. (4)) –
h	feed ration relative to fish size (Eq. (30)) g[feed]/g[BM]
K	catabolic rate coefficient (Eq. (10)) 1/day
L	fish length (Eq. (9)) cm
M	mass of individual fish (Eq. (2)) g[BM]/fish
m	fish size coefficient (Eq. (60)) (g[BM]/fish)/cm^n
n	exponent of fish length (Eq. (60)) –
p	slope of growth response to temperature (Eq. (19)) $\left(\text{g[BM]/fish}\right)^{1-\nu}/(°\text{C}\cdot\text{day})$
q	slope of ingestion response to temperature (Eq. (36)) $\text{g[feed]g[BM]}^{-\alpha}/\left(\text{fish}^{(1-\alpha)}\,°\text{C}\cdot\text{day}\right)$
Q_{10}	ratio of reaction rates at 10 K difference –
r	fraction of satiation feeding (Eq. (31)) –
S	fish state vector (Eq. (1)) **
T	temperature (Eq. (2)) °C
t	time (Eq. (1)) day
u	ingestion coefficient (Eq. (38)) $\text{g[feed]g[BM]}^{-\mu}/\left(\text{fish}^{(1-\mu)}\,\text{day}\right)$
w	ingestion temperature coefficient (Eq. (38)) 1/°C
α	anabolic allometric exponent (Eq. (5)) –
β	catabolic allometric exponent (Eq. (5)) –
χ	growth size exponent (Eq. (28)) –
η	anabolic allometric coefficient (Eq. (5)) $\left(\text{g[BM]/fish}\right)^{1-\alpha}$/day
ζ	η after correction for maintenance (catabolism) (Eq. (14)) $\left(\text{g[BM]/fish}\right)^{1-\nu}$/day
κ	catabolic allometric coefficient (Eq. (5)) $\left(\text{g[BM]/fish}\right)^{1-\beta}$/day
μ	ingestion size exponent (Eq. (38)) –
ν	α after correction for maintenance (catabolism) (Eq. (14)) –
θ	growth response to ration (Eq. (32)) –
Φ	growth performance index (Eq. (13)) ***
ϕ	phase (time) shift (Eq. (58)) day
σ	specific growth rate (SGR) (Eq. (15)) 1/day
**	units may differ among vector elements
***	defined by Eq. (13) which is not dimensionally balanced
	°C rather than K is used for conformity with common practice

Subscripts

∞	at infinite time (Eq. (7))
0	when $L = 0$ (Eq. (12))
1, 2	particular cases (Eq. (24))
a	annual amplitude (Eq. (58))
i	at initial time (Eq. (21))
M	fish biomass (Eq. (4))
m	at maintenance (Eq. (39))
F	feed (Eq. (4))
G	growth threshold (Eq. (19))
r	at reference conditions (Eq. (4))
s	at satiation (Eq. (26))
T	temperature (Eq. (4))
y	annual mean (Eq. (58))
x	at inflection point (Eq. (8))

Superscripts

$\bar{}$	time average (Eq. (23))

Acronyms

BM	body mass (fresh)
FCR	feed conversion ratio
NE	north east
RAS	recirculating aquaculture system
SE	south east
SGR	specific growth rate
TGC	thermal growth coefficient

{} enclosing function arguments