Juvenile yield index to highlight intensive culture potential in tropical marine fish

Índice de rendimiento de juveniles para resaltar la potencialidad para el cultivo intensivo de peces marinos tropicales

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ABSTRACT

Juvenile seedstock availability and costs are some of the main biological aspects to be considered on species for intensive culture assessment studies, together with market importance and performance under culture conditions, especially the growth rate and yields. A juvenile yield index (JYi) is described, as one of the judgment indicator of juvenile efficiency utilization on edible size culture production of tropical marine fishes. This index is expressed as the number of juveniles required per metric ton per year, and combines fish growth rate during grow-out, survival, and commercial size at harvest. The JYi could be combined with production costs and wholesale prices, to estimate a juvenile gross profit index (JGPi), and expressed in terms of estimated gross profit per juvenile number required per ton produced per year.

Key words: Tropical marine fishes, juveniles, juvenile yield index, intensive culture potential.

RESUMEN

La disponibilidad y costos de los organismos juveniles que serán criados están entre los principales aspectos biológicos a considerar en los estudios de evaluación de especies para el cultivo intensivo, además de la importancia comercial y el comportamiento de los organismos bajo condiciones de cultivo, especialmente la tasa de crecimiento y los rendimientos. Se describe un índice de rendimiento de juveniles (IRJ) como uno de los indicadores para evaluar la eficiencia en la utilización de juveniles en la producción del cultivo de peces marinos tropicales de talla comestible. Este índice está expresado como el número de juveniles requerido para cada tonelada métrica por año y combina la tasa de crecimiento durante la engorda, la supervivencia y la talla comercial a la cosecha. Es posible combinar el IRJ de rendimiento de juveniles con los costos de producción y los precios mayoristas, para estimar un índice de ganancias brutas de juveniles y expresar en términos de ganancia bruta el número de juveniles requerido por tonelada producida al año.

Palabras clave: Peces marinos tropicales, juveniles, índice de rendimiento de juveniles, potencialidad para el cultivo intensivo.

INTRODUCTION

There is a continuous search for new species to culture for national and international markets (Leung *et al.*, 2007; Cross *et al.*, 2008). Marine fish species that have been investigated for intensive culture over the last decades are mostly carnivorous species with a high market value (Beveridge & Haylor, 1998), based on several important criteria to assess culture potentialities. Among the important criteria to be considered in species selection procedures are juvenile availability and production costs, as well as efficiency performance, especially on mean absolute growth, survival and yield, under culture systems and various conditions. Final harvest size is also important to address in relation to processing industry requirements for high value-added benefit (Suquet *et al*., 2002; Ottolenghi *et al*., 2004). These parameters, which determine production and economic efficiency, usually decide the success of a farming operation.

Availability of wild juveniles, with rare exceptions, has been low, variable and costly (Álvarez-Lajonchère & Taylor, 2003), while technologies for their controlled mass production can often be difficult and has been slow to develop, requiring up to 10 years (Muir & Young, 1998) or even more in developing countries (Álvarez-Lajonchère, 2005).

Production of required quantities of high quality finfish juveniles at the right time and at reasonable cost is the main goal that marine fish culture has to achieve before commercial fish cultivation can be sustainable (Álvarez-Lajonchère *et al*., 2007). At the same time, operational costs for intensive tropical marine fish juvenile production and cultivation are very high, and their nursery and grow-out phases are subject to a range of environmental and market-based risks (Jones, 1972; Weber & Riordan, 1975; Le François *et al*., 2002; Álvarez-Lajonchère & Taylor, 2003; Leung *et al*., 2007). Thus, it is important to assure efficacy in all aspects and phases of the rearing process from juveniles to harvest.

In Latin America, marine fish culture research started more than 40 years ago, but there are only a few pilot-scale and commercial under operation. Thus, it is important that new projects become operational on a short term, and candidate species to be selected must have culture technologies already developed, which have been and are being commercially cultured with profit (Benetti *et al.* 1998). Although most of these aspects will depend on farmer involvement and technology development levels, these can be reduced by choosing data of aged production trail reports.

The object of the present study was to combine some of the assessment criteria in a new juvenile efficiency utilization index, which could highlight culture potential of tropical marine fishes as one of the judgment indicators of species culture potential as part of assessment, evaluation and selection processes for Latin America, especially during a pre-selection stage.

MATERIAL AND METHODS

A juvenile yield index (JYi) was conceived to assist intensive culture assessments of marine fish, combining several of the important criteria, as growth rate and mortality during the whole rearing cycle to commercial size. JYi considers the number of juveniles required to be stocked and reared up to marketable size for a mean standard production of one metric ton per year.

JYi considers the species growth rate and the estimated mean survival, calculated from the following equation:

$$X - MX = 1000/AGR\ (a/b)$$

$$X\ (1 - M) = 1000/AGR\ (a/b)$$

where: X = number of juveniles.

M = mean estimated mortality (%).

AGR = absolute growth rate during nursery and grow-out to commercial size (g/day).

a = factor for converting days to years (365)

b = factor for converting g to kg (1000)

The evaluation of JYi was carried out calculating the index for three data sets (Table 1) on best consistent maximum absolute growth rate (AGR) and the estimated mortality during nursery and grow-out trials to commercial size of: a) results obtained on experimental scale trials; b) results on pilot-scale trials; c) reports on commercial scale operations. The species location were specified on Table 1, those from tropical marine fishes present in Latin American and the Caribbean waters with culture performance reports considered among the best observed of each species taken from medium or long-term culture activities, those from species which are or have been intensively cultured at experimental scale in Latin America and the Caribbean region (Gómez Gaspar & Cervigón, 1987; Thouard *et al*., 1990; Tucker & Jory, 1991; FAO, 1994; Benetti *et al*., 1998; Gómez, 2002), and those from some traditional established species cultured on similar latitude and temperature range in other regions. Data were taken from the literature, referred by experts or directly obtained by the authors, following considerations described by Binohlan and Froese (2009) from FishBase (http://www.fishbase.org/search.php).

RESULTS

The information on AGR obtained about tropical marine fishes with commercial importance present along Latin American coasts and some traditional established species in other tropical or subtropical regions was prepared to calculate the relationships between these parameters (Table 1). The calculated JYi (Fig. 1) showed great differences between species, from less than about 1000 juveniles required for production of every metric ton per year to about 5000 among the species considered. A few species with a juvenile yield index of about 1000 or less are those with the highest performance: cobia *Rachycentron canadum* (Linné, 1766), Goldstriped amberjack *Seriola lalandi* Valenciennes, 1833, Great amberjack *Seriola dumerili* (Risso, 1810), Almaco jack *Seriola rivoliana* Cuvier, 1833, and red drum *Sciaenops ocellatus* (Linné, 1766). Another group of species with JYi between 1000 and 2000 and a moderate and acceptable culture performance are: mul-

Table 1. Absolute growth rate (AGR) and common mortality in rearing trials of 27 marine fish species present or introduced in Latin America and some traditionally cultured in other regions obtained from various sources.

Work Scale/Scientific name	Common name	AGR (g/day)	BW (kg)/ period (month)	Mortality (%)	Location	Reference
EXPERIMENTAL SCALE						
Centropomus parallelus Poey, 1860[1]	Fat snook	0.7	0.4/18	20	Florianópolis, Brazil	Cerqueira (2005)
C. *undecimalis* (Bloch, 1792)[1]	Common snook	2.2	0.8/12	20	Campeche, México	Tucker (1987), Sánchez *et al.* (2002)
Chaetodipterus faber (Broussonet, 1782)[1]	Atlantic spadefish	0.9	0.33/12	5	Mochima, Venezuela	Gómez & Larez (1984)
Epinephelus striatus (Bloch, 1792)[1]	Nassau grouper	3.0	1.8/20	10[4]	Florida, USA	Tucker (1999)
Lutjanus aratus (Günther, 1864)[1]	Mullet snapper	3.0	1.1/12	20[4]	B.C.S., México	Avilés-Quevedo & Castello-Orvay (2003)
Ocyurus chrysurus (Bloch, 1791)[1]	Yellowtail snapper	0.7	0.6/30	20[7]	Texas, USA	Turano *et al.* (2000)
L. campechanus (Poey, 1860)[1]	Northern red snapper	1.4	0.5/12	20[7]	Hawaii, USA	Laidley *et al.* (2004)
L. peru (Nichols & Murphy, 1922)[1]	Pacific red snapper	2.3	0.86/12	15	B.C.S., México	Avilés-Quevedo & Castello-Orvay (2003)
L. griseus (Linné, 1758)[1]	Grey snapper	0.9	0.19/7	14	Venezuela	León *et al.* (1966)
L. guttatus (Steindachner, 1869)[1]	Spotted rose snapper	1.2	0.45/12	20	Mazatlán, México	L. Álvarez-Lajonchère (p.o.)
L. argentiventris (Peters, 1869)[1]	Yellow snapper	0.9	0.33/12	20[4]	B.C.S., México	Avilés-Quevedo & Castello-Orvay (2003)
L. apodus (Walbaum, 1792)[1]	Schoolmaster snapper	0.8	0.2/8	20	Martinique	France Aquaculture (1985)
PILOT SCALE						
L. analis (Cuvier, 1828)[1]	Mutton snapper	1.2	0.45/12	30	Culebra, Puerto Rico	Watanabe (2001), Benetti *et al.* (2002)
L. johnii (Bloch, 1792)[3]	John's snapper	1.7	0.6/12	3	Darwin, Australia	G. Shipp (Darwin Aquaculture Centre, p.c.)
Sciaenops ocellatus (Linné, 1766)[1]	Red drum	3.5	0.9/8.7	23	Martinique	Goyard & Falguiere (1997)
Seriola lalandi Valenciennes, 1833[1]	Goldstriped amberjack	10.4	3,1/10	20[4]	B.C.S., México	Avilés-Quevedo & Castelló-Orvay (2004)
Paralabrax maculatofasciatus (Steindachner, 1868)[1]	Spotted sand bass	1.4	0.5/8	10	B.C.S., México	Avilés-Quevedo *et al.* (1995)
Seriola dumerili (Risso, 1810)[1]	Great amberjack	5.6	3/18	20[7]	Corsica, France	Cardona-Pascual (1993), Muraccioli *et al.* (2002)
Trachinotus falcatus (Linné, 1758)[1]	Permit	2.5	0.9/12	20	Martinique	France Aquaculture (1985)
Trachinotus carolinus (Linné, 1766)[1]	Florida pompano	2.3	0.44/6.5	20	Florida, USA	Moe *et al.* (1968), McMaster *et al.* (2003)
Trachinotus goodie Jordan & Evermann, 1896[1]	Pompano	1.9	0.36/6	20	Martinique	Soletchnik *et al.* (1988), France Aquaculture (1985)

Table 1. (Continuation).

Work Scale/Scientific name	Common name	AGR (g/day)	BW (kg)/ period (month)	Mortality (%)	Location	Reference
COMMERCIAL SCALE						
Dicentrarchus labrax (Linné, 1758)[2,3]	European sea bass	1.1	0.45/14	20	Greece	FAO (1994)
Lates calcarifer (Bloch, 1790)[3]	Barramundi	5.6	2.25/13	20	Darwin, Australia	Schipp *et al.* (2007)
L. argentimaculatus (Peters, 1869)[3]	Mangrove red snapper	3.1	0.96/10	10[4]	Thailand	Doi & Singhagraiwan (1993)
Rachycentron canadum (Linné, 1766)[1,3]	Cobia	11	4/12	20	Belize	J. Alarcón (Marine Farms Belize, p.c.)
Seriola rivoliana Cuvier, 1833[1,3]	Almaco jack	5.1	1.38/9	10	Hawaii, USA	S. Kraul (Pacific Planktnics, p.c.)
Sparus aurata Linné, 1758[2,3]	Gilthead seabream	1.0	0.5/13	15	Israel	Kissil *et al.* (2000)

[1] Marine fish species present in Latin America. [2] Marine fish species introduced in Latin America. [3] Marine fish species traditionally cultured in other regions. [4] Estimated by us. p.c. = Personal communication.

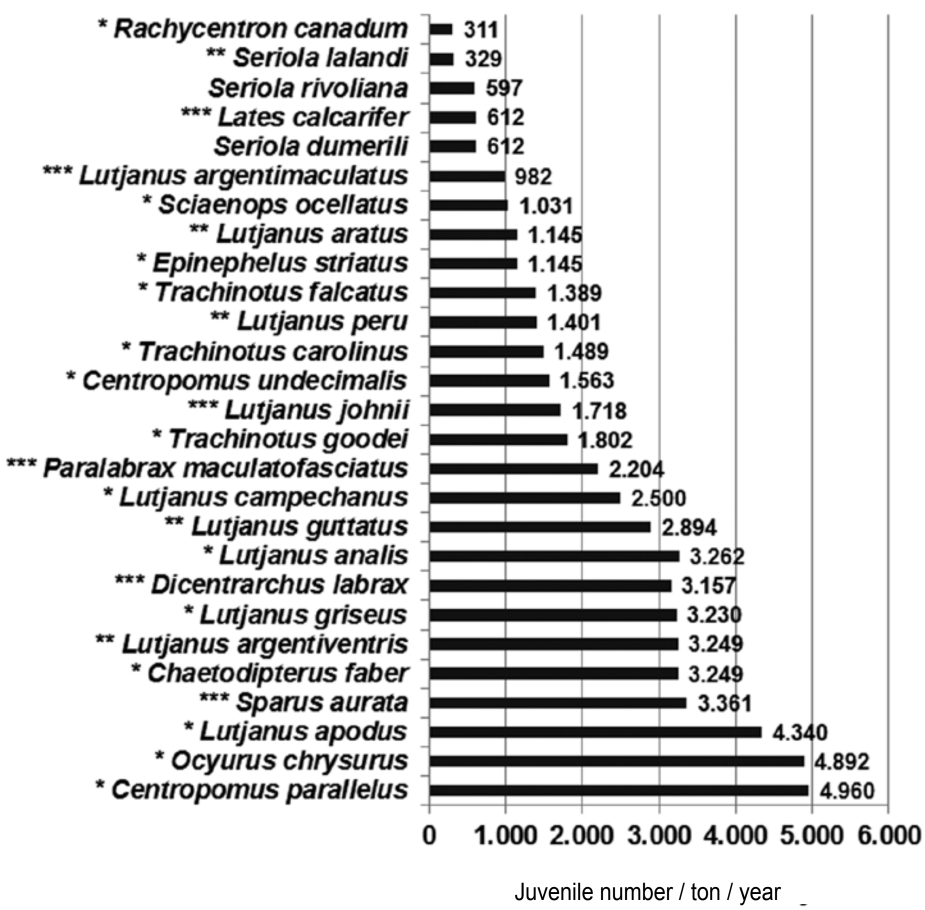

Figure 1. Number of juveniles required to be stocked to produce every metric ton per year of some tropical marine fishes. (*) present only in the Western Central Atlantic; (**) present only in the Eastern Central Pacific; (***) not present in America.

let snapper *Lutjanus aratus* (Günther, 1864), Nassau grouper *Epinephelus striatus* (Bloch, 1792), permit *Trachinotus falcatus* (Linné, 1758), Pacific red snapper *Lutjanus peru* (Nichols & Murphy, 1922), Florida pompano *Trachinotus carolinus* (Linné, 1766), common snook *Centropomus undecimalis* (Bloch, 1792), John's snapper *Lutjanus johnii* (Bloch, 1792), palometa *Trachinotus goodei* Jordan & Evermann, 1896. The rest of the analyzed species had JYi higher than 2000, which can be taken as an indication of fair to poor culture performance.

DISCUSSION

There are very few commercial projects on marine fish culture in Latin American in spite of research efforts carried out during more than 40 years. Thus, to reach commercial scale in a short term, it is considered that best species to be selected for cultivation in a region should be those on which culture technologies are already developed and have been and are being cultured commercially at a profit (Benetti *et al.,* 1998). The selection process of such species could be assisted in part by the application, as one of several criteria on a pre-selection stage, by JYi.

Also, results from the application of the JYi would be strongly influence y by farmers culture efficiencies, which are dependent on several important culture aspects as site environment parameter ranges and their fluctuations during the rearing term, culture system and intensities applied, feeds and feeding techniques, possible diseases suffered, the knowledge and experience on each species, as well as the technology development levels and farmers expertise. These variabilities could be reduced by choosing data of medium to long term production reports, especially those on pilot or commercial scales.

As farming is a business, profitability is essential, and for fish culture capital and operation costs can be high (Ottolenghi *et al.*, 2004; O'Bryen & Lee, 2007). Other important criteria to be considered are the development degree of culture technology, availability of juvenile and culture performance, as good growth, survival and food utilization, according to site and culture systems among the most important (Jones, 1972; Weber & Riordan, 1975; Pillay, 1993; Benetti *et al.*, 1998; O'Bryen & Lee, 2007).

Availability of juveniles and their efficient utilization is very important for successful commercial ventures and are one of the important indicators considered on assessment of culture potential studies, At the same time, adequate culture performance, like short rearing cycles as a result of good growth rates, are important for fast cash flows as well as reduced operational costs and possible risks for various kinds of damages, such as weather impacts, pollution, diseases, accidents, and market variations (Jones, 1972; Weber & Riordan, 1975; Álvarez-Lajonchère & Taylor, 2003).

The yield index for the number of juveniles required to produce a ton per year integrates several important biological performance features that affect rearing efficiency and technology development of the species from nursery to grow-out up to commercial size, such as growth rate, survival, and size attained at harvest. This yield index could be analyzed as part of a preliminary pre-selection stage of culture potentialities, before a full evaluation is carried out.

Juvenile cost of gilthead seabream *Sparus aurata* Linné, 1758 was calculated to be 3.3 juveniles to produce 1 kg of commercial size fish by Sweetman (2001), but not adjusted to one-year time. In the present study, the effect of time to reach commercial size was also included in the JYi that is presented as an additional tool for species culture potential assessment studies, allowing for growth rate influence. Another feature that influences the JYi of the present study is harvest size, which has been highlighted by Weber and Riordan (1975), Suquet *et al.* (2000) and Quéméner *et al.* (2002) in relation to processing possibilities as value-added products, an important criterion to consider (Ottolengthi *et al.*, 2004). Species with small harvest size are low scored for the processing industry, for which best sizes are 0.5-1 m and more than 1 kg (Suquet *et al.*, 2002).

The JYi could also be combined with total operational costs (including juvenile costs) per unit ton per year, and market wholesale prices, to calculate the profit per stocked juvenile for every ton produced per year. For some established species with JYi of 500 or less, like and established species present outstanding values, several time higher than species with poor culture performances.

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