Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: xyz

POTENTIAL MOLECULAR TOOLS FOR SEX DETERMINATION FOR YELLOWTAIL AMBERJACK *SERIOLA LALANDI* CUVIER & VALENCIENNES, 1833 (PERCIFORMES, CARANGIDAE).

Eliana Ibáñez-Arancibia[1,2,3,*], Rodolfo Wilson[4], Patricio R. De los Ríos-Escalante[4,5]

[1]PhD Program in Sciences mentioning Applied Molecular and Cell Biology, La Frontera University, Temuco, Chile
[1]Laboratory of Engineering, Biotechnology and Applied Biochemistry – LIBBA, Department of Chemical Engineering, Faculty of Engineering and Science, La Frontera University, Temuco, Chile.
[2] PhD Program in Applied Cell and Molecular Biology, La Frontera University, Temuco, Chile.
[3]Department of Biological and Chemical Sciences, Faculty of Natural Resources, Catholic University of Temuco, Temuco, Chile.
[4]Departamento de Ciencias Acuáticas y Ambientales, Facultad de Ciencias del Mar y Recursos Hidrobiológicos, Universidad de Antofagasta, Chile.
[5]Nucleus of Environmental Sciences, Faculty of Natural Resources, Catholic University of Temuco, Temuco, Chile.

***Corresponding Author:** Eliana Ibáñez-Arancibia
*E-mail: e.ibanez05@ufromail.cl

Abstract
The fish genus *Seriola* is an important marine resource for fisheries and aquaculture, mainly in Pacific coast and Europe, and it has excellent projection in aquaculture due its fast growth and excellent flesh quality, within this genus *S. lalandi* is an important resource for Chilean aquaculture. The aim of the present study was do a literature review of potential non destructive tools for sex determination for adults of *S. lalandi* with their potential applications on aquaculture. The literature described that *Seriola* genus has not sexual dimorphism, and the sex determination is possible using molecular and genetical tools that involves sacrifice individuals, nevertheless it would be possible sex determination using immunological test on skin mucus in adults for determine vitellogenin levels, that shows in first studies its presence in high levels in females in comparison to males. The present study would propose the use of this technical for potential sex determination for *Seriola lalandi* as well as other species of *Seriola* genus.

Keywords: *Seriola*, aquaculture, sex determination, immunological tools, skin mucus.

Introduction

The marine fish species of genus *Seriola* are important resources for aquaculture (García and Diaz, 1995; Papandroulakis et al. 1995; Fernandez et al. 2015; Quiñones-Arreola et al. 2015; Fernandez-Montero et al. 2018; Rotman et al. 2021). One of these species is *Seriola lalandi* Cuvier & Valenciennes, 1833 (Perciformes, Carangidae), that inhabits the Asia, in American Pacific coast and Europe (Fernandez et al. 2015; Martinez-Montaño et al. 2016; Orellana et al. 2014). *S. lalandi* is cultured in Japan and New Zealand, due its relatively fast growth and excellent flesh quality (Jara et

al. 2017). It is also present in Chile, and it has high potential in local aquaculture (Leyton et al. 2017; Ramos & Gallardo, 2021).

The genus *Seriola* includes many species important for fisheries and aquaculture such as *S. aureovittata, S. dorsalis, S. dumerili, S. quinqueradiata*, and in each studies, it was genetical population genetic structure described (Pemachandra et al. 2017; Šegvić Bubić et al. 2017; Zupa et al. 2017; Purcell et al. 2018; Li et al. 2022). Also, the literature on *S. lalandi* involves basic population characteristics (Nocillado et al. 2012; Purcell et al. 2015; Premachandra et al. 2017; Sarropoulu et al. 2017; Dettlef et al. 2020), growth and development (Wang et al. 2020, 2021; Shi et al. 2021), these studies were based mainly on DNA sequentiation and proteins expression. There is absence of sexual dimorphism for *Seriola* genus (Šegvić Bubić et al. 2017), and it is possible found differences using immunology techniques on skin mucus (Takemura et al. 1996, 1999). Also, described the molecular method associated with gametic or embryonic development or spawing induction for *S. dorsalis* (Purcell et al., 2018), *S. dumerili* (Zupa et al. 2017), and *S. quinqueradiata* (Fuji et al. 2010; Higuchi et al. 2016; 2017a,b). On this basis, we performed literature review on molecular procedures and their potential application on reproductive manipulaton of on *S. lalandi* applied to aquaculture.

For *S. dorsalis* Purcell et al. (2018), described the presence of differences at the DNA level, DNA sequencing showing differences in the *hsd17b3* and *sox3* genes, that were reported as important for sex determination in fishes (Matsuda et al. 2002; Budd et al. 2015), also, it was proposed the use of steroid hormones was proposal for adults individuals, that are not destructive because were collected a pat of fin for ELIZA method (Aoki et al. 2020).

Due the absence of similar antecedents for *S. lalandi* it would be necessary apply the procedures described by Takemura et al. (1996) and/or Purcell et al. (2018). Probably the most economic and applicable procedure would be replicate the methodology applied by Takemura et al. (1996, 1999) for *S. dumerlii* that needs only immunology samples from skin mucous, this would be a non-destructive technique that was described for farmed fishes such as salmonids (Pottinger et al., 2005). On the basis of the results of Takemura et al. (1996), what was significantly more higher in females than males. Vitellogenin in mucus was detectable only in females, whereas it was not detectable in males, based in observations for fishes of two and three years of age (Table 1), because in fishes of one year age the sensitivity was lower (Table 2).

As conclusion, the literature review mentioned that fishes examined for sex determination were sacrified (Purcell et al., 2018), this would be a disadvantage for apply in fish farmings. The non-destructive techniques proposed by Takemura et al. (1996, 1999), does not sacrifice the fishes, and the sampling procedure would be more economics in terms of avoiding killing fishes for sex ratio estimation for the population, and the methodology for study would be more economic than DNA sequencing. These techniques could be developed for other species of genus *Seriola* important for fisheries and aquaculture.

Acknowledgements

The authors express their gratitude to the doctoral scholarship ANID 21191555, and project MECESUP UCT 0804 for funding this study. Thanks to S.T. and M.I. for your comments.

References

1. Aoki R, Chuda H, Washio Y, Masuma, Kato K. Sex discrimination of cultured greater amberjack *Seriola dumerili* using steroid hormones. Fish. Sci., 2020; 86, 57–64.
2. Budd AM, Banh QQ, Domingos JA, Jerry DR. Sex control in fish: approaches, challenges and opportunities for aquaculture. J. Mar. Sci. Eng., 2015; 3, 329-355.
3. Dettleff P, Hernandez E, Patridge G, Cruz F, Martínez V. Understanding the population structure and reproductive behavior of hatchery-produced yellowtail kingfish (*Seriola lalandi*). Aquaculture, 2020; 522, 734948.

4. Fernandez G, Cichero D, Patel A, Martínez V. Genetic structure of Chilean populations of *Seriola lalandi* for the diversification of the national aquaculture in the north of Chile. Latin American J. Aq. Res., 2015; 43, 374-379.
5. Fernández-Montero A, Caballero MJ, Torrecillas S, Tuset VM, Lombarte A, Ruiz Ginés R, Robaina R, Montero D. Effect of temperature on growth performance of greater amberjack (*Seriola dumerili* Risso 1810) Juveniles. Aquacult. Res. 2018; 49(2), 908– 918.
6. Fuji K, Yoshida K, Hattori K, Ozaki A, Araki K, Okauchi M, Kubota S, Okamoto N. Identification of the sex-linked locus in yellowtail, *Seriola quinqueradiata*. Aquaculture. 2010; 308, s51-s55.
7. García A, Díaz M.V. Culture of *Seriola dumerilii*. Marine aquaculture finfish species diversification. Zaragoza: CIHEAM, 1995; 103-114 (Cahiers Options Méditerranéennes; n. 16)
8. Higuchi K, Gen K, Izumida D, Kazeto Y, Hotta T, Takashi T, Aono H, Soyano K. Changes in gene expression and cellular localization of insulin-like growth factors 1 and 2 in the ovaries during ovary development of the yellowtail, *Seriola quinqueradiata*. Gen. Comp. Endocrinol., 2016; 232, 86-95.
9. Higuchi K, Yoshida K, Gen K, Matsunari H, Takashi T, Mushiaje K, Soyano K. Effect of long-term food restriction on reproductive performances in female yellowtail, *Seriola quinqueradiata*. Aquaculture, 2017a; 486, 224-231.
10. Higuchi K, Gen K, Izumida D, Kazeto Y, Hotta T, Takashi T, Aono H, Soyano K. Changes in plasma steroid levels and gene expression of pituitary gonadotropins, testicular steroidogenesis-related proteins and insulin-like growth factors during spermatogenesis of the yellowtail *Seriola quinqueradiata.* Fish. Sci., 2016; 83, 35–46.
11. Jara B, Abarca M, Wilson R, Kaprivka S, Mercado A, Guiñez R, Marchant R. Qualitative analysis of cartilaginous jaw element malformation in cultured yellowtail kingfish (*Seriola lalandi*) larvae. Aquacult. Res, 2017; 48, 4420-4428.
12. Leyton Y, Sayes C, Mejias C, Abarca M, Wilson R, Riquelme C. Increased larval survival of *Seriola lalandi* using *Pseudoalteromonas* sp. as probiotics. Rev. Biol. Mar. Ocean., 2017; 52, 95-101
13. Li M, Xu X, Liu S, Fan G, Zhou Q, Chen S. The chromosome-level genome assembly of the Japanese yellowtail jack *Seriola aureovittata* provides insights into genome evolution and efficient oxygen transport. Mol. Ecol. Res., 2022; 22, 2701-2712.
14. Martínez-Montaño E, González-Álvarez K, Lazo JP, Audelo-Naranjo JM, Vélez-Medel A. Morphological development and allometric growth of yellowtail kingfish *Seriola lalandi* V. larvae under culture conditions. Aquacult. Res., 2016; 47, 1277-1287.
15. Matsuda M, Nagahama Y, Shinomiya A, Sato T, Matsuda C, Kobayashi T, Morrey CE, Shibata N, Asakawa S, Shimizu N, Hori H, Hamaguchi S, Salaizumi M. DMY is a Y-specific DM-domain gene required for male development in the medaka fish. Nature, 2002; 417(6888), 559–563.
16. Nocillado JN, Biran J, Lee YY, Levavi-Sivan B, Mechaly AS, Zohar Y, Elizur A. The Kiss2 receptor (*Kiss2r*) gene in southern bluefin tuna, *Thunnus maccoyii* and in yellowtail kingfish, *Seriola lalandi* - functional analysis and isolation of transcript variants. Mol. Cell Endocrinol., 2012; 15, 211-20.
17. Orellana J, Waller U, Wecker B. Culture of yellowtail kingfish (*Seriola lalandi*) in a marine recirculating aquaculture system (RAS) with artificial seawater. Aquacult. Eng., 2014; 58, 20-28.
18. Papandroulakis N, Mylonas C, Maingot E, Divanach P. First results of greater amberjack (*Seriola dumerili*) larval rearing in mesocosm. Aquaculture, 2005; 250, 155-161.
19. Pottinger TG, Pulman KGT, Carrick TR, Scott AP Evaluation of biochemical methods for the non-destructive identification of sex in upstream migrating salmon and sea trout. J. Fish Biol., 2005; 67, 1514-1533.

20. Premachandra HKA, La Cruz FL, Takeuchi Y, Miller A, Fielder S, O´Connor W, Frere CH, Nguyen NH, Bar I, Knibb W. Genomic DNA variation confirmed *Seriola lalandi* comprises three different populations in the Pacific, but with recent divergence. Sci. Rep., 2017; 7, 9386.
21. Purcell CM, Chabot CL, Craig MT, Martinez-Takeshita N, Allen LG, Hyde JR. Developing a genetic baseline for the yellowtail amberjack species complex, *Seriola lalandi* sensu lato, to assess and preserve variation in wild populations of these globally important aquaculture species. Cons. Genet. 2015; 16, 1475–1488.
22. Purcell CM, Seetharam AS, Snodgrass O, Ortega-García S, Hyde JR, Severin AJ. Insights into teleost sex determination from the *Seriola dorsalis* genome assembly. BMC Genomics,2018; 19, 31.
23. Quiñones-Arreola MF, Arcos-Ortega GF, Gracia-López V, Casillas-Hernandez R, Wreich C, Morris T, Diaz-Tenorio M, Ibarra-Gamez JC. Reproductive broodstock performance and egg quality of wild-caught and first-generation domesticated *Seriola rivoliana* reared under same culture conditions. Latin American J. Aq. Res., 2015; 43, 953-962.
24. Ramos R, Gallardo S. Capacidad de biofiltración de nutrientes y crecimiento de macroalgas utilizando efluentes generados en el cultivo del pez dorado *Seriola lalandi* (Perciformes: Carangidae). Rev. Biol. Mar. Ocean., 2012; 56, 13-21.
25. Rotman F, Stuart K, Silbernagel C, Drawbridge M. The status of California yellowtail *Seriola dorsalis* as a commercially ready species for marine U.S. aquaculture. J. World Aquacult. Soc., 2012; 52, 595– 606.
26. Sarropoulou E, Sundaram AYM, Kaitetzidou E, Kotoulas G, Gilfillan G, Papandroulakis N, Mylonas CC, Magoulas A. Full genome survey and dynamics of gene expression in the greater amberjack *Seriola dumerili*. Gigascience. 2017; 6, 1-13.
27. Šegvić Bubić T, Marrone F, Grubišić L, Izquierdo-Gomez D, Katavic I, Arculeo M, Lo Brutto S. Two seas, two lineages: How genetic diversity is structured in Atlantic and Mediterranean greater amberjack *Seriola dumerili* Risso, 1810 (Perciformes, Carangidae). Fish. Res., 2016; 179, 271-279.
28. Shi B, Sun R, Liu X, Zhang Z, Xu Y, Jiang Y, Wang B. Molecular cloning, characterization and expression profile of *Myf5* and *Myf6* during growth and development in the *Seriola lalandi*. J. Ocean Univ. of China, 2021; 20, 1597–1605.
29. Takemura A, Kanematsu M, Oka M. Early sex distinction in greater amberjack *Seriola dumerili* using skin mucus. Bull. Japanese Soc. Sci. Fish. (Japan), 1996; 62, 62-67
30. Takemura A, Takeuchi H, Teruya K, Oka M, Kanematsu M. Immunochemical estimation of reproductive activity in hatchery-reared female greater amberjack, *Seriola dumerili*, using skin mucus. Fish. Sci., 1999; 65, 792-793.
31. Wang B, Zhang Y, Liu Q, Xu Y, Cui A, Jiang Y, Liu X. Molecular identification and developmental expression patterns of growth hormone and its receptors in yellowtail kingfish (*Seriola lalandi*). Mol. Biol. Rep., 2020; 47, 7305-7312.
32. Wang B, Zhang Y, Cui A, Liu Y, Jiang Y, Wang L, Liu X. LPXRFa and its receptor in yellowtail kingfish (*Seriola lalandi*): Molecular cloning, ontogenetic expression profiles, and stimulatory effects on growth hormone and gonadotropin gene expression. Gen. Comp. Endocrinol., 2021; 312, 113872.
33. Zupa R, Rodríguez C, Mylonas CC, Rossenfeld H, Fakriadis I, Papadaki M, Perez JA, Pousis C, Basilone G, Corriero A. Comparative study of reproductive development in wild and captive-reared greater amberjack *Seriola dumerili* (Risso, 1810). PLoS ONE, 2017; 12, e0169645.

Table 1. Vitellogenin concentration in the skin mucus of *Seriola dumerili* [Cf: Takemura et al., 1996, page 65.]

Age (year)	*N*	Mucus protein (mg/ml)	Mucus vitellogenin (ng/mg protein)
2+ female	7	16.76 ± 2.15	81.80 ± 71.06
2+ male	8	19.02 ± 1.53	Not detectable
2+ female	9	14.06 ± 1.50	80.10 ± 32.30
3+ male	5	18.55 ± 2.89	Not detectable

Table 2. Detection of mucus and serum vitellogenin before spawning season of *Seriola dumerili* [Cf: Takemura et al., 1996, page 65.]

N	January		February	
	Serum (mg/ml)	Mucus (ng/mg protein)	Serum (mg/ml)	Mucus (ng/mg protein)
1	72.51	2.79	95.02	5.12
2	----	7.60	137.53	4.22
3	----	----	----	----
4	----	----	750.15	4.87
5	----	----	----	----
6	----	----	----	----
7	----	----	----	----
8	----	----	----	----