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Effectiveness of stock enhancement of hatchery-released black rockfish *Sebastes schlegeli* in Yamada Bay — Evaluation by a Fish Market survey

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Abstract

Black rockfish *Sebastes schlegeli* is considered a promising species for stock enhancement because of its high growth rate and limited area of movement. This study evaluated the stocking effectiveness of black rockfish released in Yamada Bay, off the northeastern Pacific coast of Japan, using three indices estimated from survey data collected on all business days at the Yamada Fish Market over a period of 11 years. Eight annual cohorts of hatchery-raised, marked juveniles were released into the bay from 1989–1991 and 1993–1997. During the market census, all landed black rockfish were investigated for TL and presence or absence of marks. The census indicated that 51,512 fish out of 447,400 hatchery-released juveniles were landed commercially and recorded at the market. Of the returned fish, 1-year-old fish accounted for 61.2%, 2-year-old fish for 30.3%, and ≧3 year-old fish for 8.6%. Return rates of each year class ranged from 9.3% to 15.4% showing stable and rather high values. However, the economic return rate (landed sales values / hatchery costs) ranged between 0.68 and 1.25; 5 of the 8 year classes showed rates of less than 1, where hatchery costs exceeded their associated benefit. To make stocking of black rockfish feasible, raising the market price of this species through fishery management, decreasing hatchery production costs, and developing effective release strategies such as optimum release size are needed.

Keywords: Black rockfish; *Sebastes schlegeli*; Stock enhancement; Return rate; Economic return rate; Fish market survey

1. Introduction

The black rockfish *Sebastes schlegeli* is a viviparous teleost belonging to the Scorpaenidae. It is distributed along the coasts of Japan, Korea, and China. In all, 69 species of the genus *Sebastes* have been reported from the North Pacific Ocean and 32 species from coastal areas of Japan (Boehlert and Yamada, 1991). Many species in this genus are important as a commercial and recreational fishing resource (Kusakari, 1995; Nagasawa, 2001). Commercial landings of *Sebastes* fishes, including black rockfish, have decreased remarkably from 54,310 tons in 1976 to 2,006 tons in 1986 in Japan (Boehlert and

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Yamada, 1991). All landed *Sebastes* species are combined as one item (rockfishes) in the statistical data of fish markets. Therefore, it is difficult to obtain precise landing data for black rockfish to estimate annual changes in landings of this species. However, because black rockfish dominates the genus *Sebastes* in Iwate prefecture, it is inferred that black rockfish catch has declined (Nakagawa unpubl.).

Stock enhancement is a management tool that might augment depleted wild populations of marine living resources by supplementing or restoring the stocks (Munro and Bell, 1997; Willis et al., 1995; Blaxter, 2000). Striped mullet *Mugil cephalus* (Leber and Arce, 1996); striped bass *Morone saxatilis* (Secor and Houde, 1998); Red sea bream *Pagrus major* (Kitada, 1999), and Japanese flounder *Paralichthys olivaceus* (Iwamoto et al., 1998; Kitada, 1999; Okouchi et al., 1999, 2004; Atsuchi and Masuda, 2004) are marine fish species that have shown potential use for effective stock enhancement. Stocking of black rockfish has been conducted since 1990: 1.7 million hatchery-raised juveniles were released in 2002 in Japan (Fisheries Agency and National Center for Stock Enhancement Fisheries Agency, 2004). In Korea, this species is also important for coastal fisheries; hatchery fish have been stocked for 9 years (J. Gwak, pers. comm.). Growth of black rockfish is more rapid than that of other rockfish species (Kusakari, 1995; Nagasawa, 2001); also, their range of movement is limited (Sasaki et al., 2005; Nakagawa unpubl., this paper). For those reasons, black rockfish is considered to be a promising target fish species for stock enhancement. In this paper, we evaluated the effectiveness of a stock enhancement program of hatchery-raised black rockfish juveniles released into Yamada Bay, using a market census of all landed fish on all business days at the Yamada Fish Market over an 11-year-period.

2. Materials and methods

2.1. Market and release of juvenile fish

A total of 447,400 juvenile black rockfish were produced at the Miyako Station, Fisheries Research Agency (FRA), located in Iwate Prefecture, northeastern Japan. Hatchery fish were transported and released in Yamada Bay 30 km south of the Miyako Station during 1989–1991 and 1993–1997 (Table 1). In 1992, the release was not made because of problems in fish production at the Miyako Station. Stocking of this species has not been carried out in Yamada Bay since 1998. In Iwate Prefecture, wild black rockfish deliver larvae mainly in June (Nakagawa unpubl.). At the Miyako Station, females delivered larvae from May to early June (Nakagawa and Okouchi, 2005), and juveniles were released between Aug. 31 and Oct. 27 at a mean total length (TL) of 8 to 13 cm. Before release, one side of the ventral fin (the left side for 1989–1994 and 1996 year classes and right side for 1995 and 1997 year classes) was removed, using a plier-like tool, as a mark to distinguish hatchery-released fish from wild fish. Of the hatchery fish released in 1989 and 1990, 48.3% and 50.4% were marked, respectively. All released fish since 1991 have been marked (Table 1). The numbers of returned hatchery fish for 1989 and 1990 year classes were converted using these marking rates. In 1995–1997 released year classes, 100 juveniles for each year were randomly sampled immediately after marking and reared in a 1000-L tank for one year to examine the rate of fin regeneration (loss of mark). We did not check the rate of fin regeneration for the 1989–1994 year classes. The number of landed hatchery fish was calculated using the fin regeneration rate. The average value of the regeneration rate of the above three years was used for the 1989–1994 year classes (Table 1).

Table 1
Release statistics of black rockfish in Yamada Bay

Year of release	Number of release	Mean TL (mm)	Release site	Date of release	Marking method*1	Mark rate (%)	Mark regeneration rate (%)
1989	62,600	89	Inside of bay	Oct 26	Fin removal(L)	48.3	16.7*2
1990	180,200	81	Inside of bay	Aug 31, Sep 18	Fin removal(L)	50.4	16.7*2
1991	27,700	105	inside of bay	Oct 16	Fin removal(L)	100.0	16.7*2
1992	0	–		–	–	–	
1993	59,000	98	Inside of bay	Oct 7	Fin removal(L)	100.0	16.7*2
1994	50,000	129	Mouth of bay	OCt 27	Fin removal(L)	100.0	16.7*2
1995	19,000	102	Mouth of bay	Aug 31	Fin removal(L)	100.0	24.0
1996	20,000	102	Mouth of bay	Sep 7	Fin removal(L)	100.0	16.1
1997	28,900	87	Mouth of bay	Sep 4	Fin removal(L)	100.0	10.0
Total(Average)	447,400	(99)				(87.3)	

*1(L): Left ventral fin, (R): ventral fin.
*2The average of mark regeneration rate from 1996 to 1997 was used.