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Abalone of a mouthful size reared with attached diatoms in seawater pumped from the deep water of Toyama Bay

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Abstract

Juvenile shells (37 and 47 mm in shell length) of the abalone, *Nordotis discus* hannai, were cultured in outdoor tanks in the course of multiple/ cascade utilization of deep-sea water (cold, clean nutrient-rich seawater endemicto Sea of Japan) pumped from a depth of 321 m in Toyama Bay. In the culture, heated deep-sea water (12℃) consisting of water from a heat-exchanger (operating between deep-sea water of 3 ℃ and underground freshwater of 17℃ for culturing masu salmon, *Oncorhynchus masou*) was used. Attached diatoms blooming in the tank (and encrusting green micro-algae, *Ulvella lens*, blooming after accidental invasion) were fed to abalone. After ten months, the abalone reached minimum commercial size (60mm in SL), what is called a mouthful size without any mass mortality. Outer surface of the newly excreted shells was comparatively smooth because of constant ambient water temperature. This is the first demonstration showing the use of 'too cold' deep-sea water of Toyama Bay in aquaculture of temperate shallow water species of shellfish.

Key words; abalone, aquaculture, deep-sea water, heat exchanger, *Oncorhynchus masou, Nordotis discus hannai*

In Toyama Prefecture, deep-sea water (DSW) has been pumped up from a depth of 321m off Toyama Prefectural Fisheries Research Institute in Namerikawa City since 1995. Because of its coldness (ca. 3 ℃ after pumping to the surface) as well as cleanliness, DSW has been used to keep brood stocks of cold water species such as Masu salmon, *Oncorhynchus masou*, serving as ambient water during its seawater life and as a cold source for heat-exchange during its fresh water life. It has also been used to maintain deep sea water species such as coon-striped shrimp, *Pandalus hypsinotus*. Another characteristic of DSW is its richness in nutrients such that it fulfills one of the objectives in our program of multiple/cascade deep-sea water utilization. The author paid attention to the extensive cover of attached diatoms found in outdoor DSW tanks, and found that

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juvenile shells of a northern form of abalone, *Nordotis discus hannai*, grew well up to what we call 'a mouthful size', 60mm, just by only feeding on them.

In the culture of abalone, DSW（HEDSW, 12℃）heat-exchanged with underground freshwater（17℃）was used, because it was not too cold and available from the culture system for brood-stocking of masu salmon. HEDSW was poured into an outdoor tank（0.9×1.8×0.7m）at a rate of 24 liter/min and kept without introducing any animals for a month. In a few weeks, attached diatoms, which derived from DSW（probably sinking from shallow water）visibly covered the walls and bottom of the tank. The diatom community was comprised of both solitary and colonial species（20 species of 13 genera）, including *Achnanthes longipes* which brought better growth of *N. discus hannai* than kelp *Laminaria japonica*（Takami *et al.* 1996）. Diatom flora in the tank is described in detail elsewhere（Suzuki *et al.* 2000）. From June, 1999, however, small encrusting green algae *Ulvella lens* has been dominant and covered all of the inner surfaces of the tank. The algae was probably derived from short-term-deposited intertidal snails and adapted to abalone grazing together with sessile diatoms such as *Cocconeis* spp.

Abalone culture was started with 10 juvenile shells（37mm in shell length（SL））on July 1, 1998. Then 50 larger shells（47mm in SL）were added on October 9, 1998, together with two cases of corrugated plates（made of polyvinyl chloride, 30×30cm×10 sheets/case）to increase the diatom-covered area. These abalones were the shells produced in Toyama Prefectural Sea Farming Center in autumn of 1996. The water temperature was between 9℃ and 12℃ all through the year. The tank was covered with transparent board（made of acrylic resin）as a snow shelter during winter, and any accumulated snow was removed once within a few days.

After culturing for one month, light-green colored shell was excreted at the margin of the abalone, which showed their growth. Grazing marks extended gradually and covered all over the inner surfaces of the tank. Abalones moved around actively with elongated tentacles particularly in the morning and evening. The active movement suggested that they were quite healthy.

After ten months, some of original 10 shells reached 60mm（Fig. 1）. The outer surface of the shell, formed by living in constant water temperature condition of HEDSW, was very smooth. Survival rate was 90%. The death of one shell was accidental; shell was broken during detachment from a corner of the tank for measuring. Among the surviving shells, one remained in original size. Genetic problems may exist in such shells. In the lately-added 50 shells, ca 40% of shells died in a month but the other shells survived and grew up to 60mm without further mortality after a year. The reason of early mortality is unknown.

Attention has also been paid by other researchers in Japan to DSW application in abalone culture. Hamai（1996）succeeded in raising tank-cultured abalone, *N. discus*

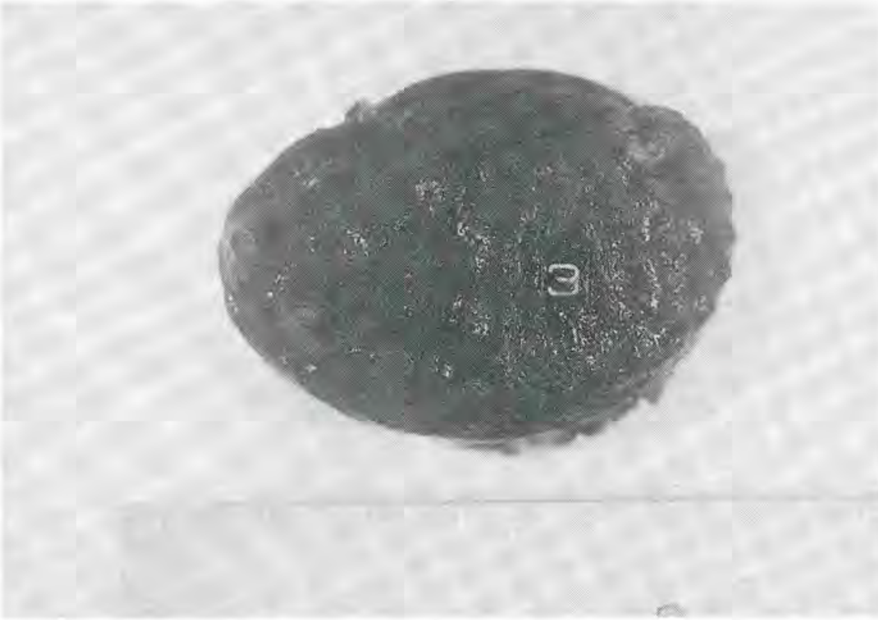

Fig. 1 Abalone of a mouthful size, *Nordotis discus hannai*, reared with attached diatoms in deep-sea water pumped from Toyama Bay.

hannai, by cooling the 'too warm' pumped shallow water with DSW. Fukami *et al.* (1997) cultured an attached species of the diatom *Nitzschia*, by using cut hoses (as a bioreactor) with flowing DSW in cylinder tanks and reared juvenile shells (25mm in SL) of *N. gigantea* (*as Haliotis sieboldii*) by allowing them to feed on them. They achieved growth of 1 mm in SL after one month. Nabeshima *et al.* (1999) reported on a land-based tank culture of *N. gigantea* by feeding kelp cultured in the waste of fish-culture water. The present report demonstrates the possibility of producing abalone of a minimum commercial size only using DSW and attached diatoms blooming in DSW.

Stock enhancement of abalone is attractive because of its high price such that tens of thousands of juvenile shells have been released in many areas of Toyama Bay since 1979 (Fujita 1998). However, the rate of released shells (Fujita & Shozen 1999) and the rate of recapture (Fujita & Seto 2000) have been quite low in Toyama Bay. Therefore, land-based culture in DSW is an alternative approach to increasing abalone in Toyama Prefecture. Particularly, HEDSW may be a good way to reduce the cost (e.g., for warming, feeding and keeping health) among DSW and their various wastes. Productivity of attached diatoms, optimum abalone density in tanks as well as combination with other food (e.g., kelp cultured in multiple/cascade culture system) will be the next targets of this study.

富山湾深層水中に繁茂する付着珪藻を用いて育成した一口アワビ

富山湾の水深321ｍから汲み上げている深層水（低温，清浄で栄養塩に富む日本海固有水）の多目的／多段利用の一段階として，屋外水槽でエゾアワビ（殻長37㎜と47㎜）の養殖を試みた。本養殖では，サクラマス飼育用の熱交換器（３℃の深層水と17℃の地下水の間で熱交換）から排出される加温深層水を用い，水槽内で繁茂した付着珪藻をアワビに摂餌させた。アワビは，10カ月後でも目立ったへい死がなく，一口アワビと呼ばれる最小流通サイズ（殻長60㎜）に成長した。飼育水が恒温であるため，新たに分泌された殻の外表面は比較的滑らかであった。これは，「冷たすぎる」深層水（日本海固有水）を温帯性浅海種の周年養殖に活用した最初の事例である。

References

Fujita, D. 1998. Awabi. (Ed. Toyama Prefectural Fishieries Research Institute) Toyama-wan no sakanatachi wa ma p.40-41. Katsura Shobo. Toyama.

Fujita D. and Y. Seto 2000. Notes on released abalone in Uozu City, Toyama Prefecture. Bull. Toyama Pref. Fish. Res. Inst., **12**: 13-18.

Fujita, D. and K. Shozen 1999. Toyama-ken tobu (Kurobe-shi, Nyuuzen-machi, Asahi-machi) engan-iki no gyojou kankyo. Toyama Prefectural Fisheries Researchi Institute. 94pp. Namerikawa.

Fukami, K., A. Kawai, M. Asada, M. Okabe, T. Hotta, T. Moriyama, S. Doi, T. Nishijima, M.Yamaguchi and M. Taniguchi 1998. Continuous and simultaneous cultivation of benthic food diatom *Nitzschia* sp. and abalone *Haliotis sieboldii* by using deep seawater. J. Mar. Biotech, **6**: 237-240.

Hamai, M. 1996. Ezo-awabi shubyo soki seisan shiken. Ann. Rep. Toyama Pref. Fish. Res. Inst. (1995), 109-110.

Nabeshima, H., M. Watanabe, T. Yamamoto, M. Hiraoka 1999. Kaiyo shinso-sui ni yoru sorui baiyo to haisui no yuko riyo. P.38-39. Kaiyo Shinso-sui '99 Saga Taikai Kouen Youshishu, JADOWA.

Suzuki, H., T. Nagmumo and D. Fujita 2000. Attached diatoms bloomed in pumped-up deep-sea water of Toyama Bay. Bull. Toyama Pref. Fish. Res. Inst., **12**: 33-42.

Takami, H., T. Kawamura and Y. Yamashita 1996. Dietary value of benthic diatoms for the growth of juvenile abalone. Suisanzoshoku, **44**: 211-216.