Nils Hagen

Recent Advances in Sea-Urchin Aquaculture in Norway

Nils T. Hagen and Sten I. Siikavuopio

Sea-urchin aquaculture (echiniculture) in Norway is being developed along two separate paths with some overlap. Bodø University College (HBO) is pursuing a strategy of full domestication, with the explicit goal of bringing the entire production cycle of the sea urchin under a controlled industrial regime, whereas the Norwegian Institute of Fisheries and Aquaculture Research (NIFA) is developing techniques for gonad enhancement of wild urchins using formulated feed. Both institutions focus their R&D efforts on the green sea urchin, *Strongylocentrotus droebachiensis*. The closely related species *S. pallidus* is also being investigated at HBO, as it appears to be largely resistant to infection by the parasitic nematode *Echinomermella matsi*.[1] Nematode infection is easy to prevent in land-based echiniculture facilities using hatchery-reared juveniles, but all sea-based urchin aquaculture in northern Norway is susceptible to infection by *E. matsi*. *S. pallidus* is, therefore, targeted as an integral part of an ongoing effort to develop a disease-resistant sea-urchin variety suitable for both land-based and sea-based echiniculture.[2]

Hatchery

The only sea-urchin hatchery in Norway is located in Bodø. HBO's main emphasis is the development of methods for continuous mass production of larvae and juveniles of *Strongylocentrotus droebachiensis*. Experimental quantities of *S. pallidus* and hybrids of the two species are also being produced. The hatchery is supplied with running seawater from a depth of 250 m, where salinity and temperature remains stable at 35‰ and 7°C throughout the year.

Broodstock

Broodstock are maintained in plastic shopping baskets in a simple rearing system consisting of racks of standard salmon hatching trays. Both wild and cultivated broodstock are fed on fresh kelp, *Laminaria hyperborea* and *L. digitata*. Gametogenesis of captive broodstock is not synchronized.[3] Although gamete quantity and quality vary, it has nevertheless proved feasible to initiate spawning and start new larval cultures on a weekly basis throughout the year.

Spawning is routinely induced by intracoelomic injection of isotonic KCl solution,[4, 5] as electric stimulation is not recommended.[6] Males and females are kept separately to prevent uncontrolled female spawning. Individual identification of sea urchins is feasible by intracoelomic insertion of electronic transponder tags,[7] but the cost of tags precludes routine tagging of the entire broodstock population.

Larvae

Figure 1
Larval rearing tanks at the sea-urchin hatchery in Bodø, Norway.

Larvae are reared in 160-L tanks with a cone-shaped bottom, and a gentle flow of filtered seawater (Figure 1). Water drains through a central standpipe with a double banjo filter, and the water level is controlled by an external overflow pipe. Larvae are kept in suspension by gentle aeration or with mechanical agitation by a submerged plastic propeller. Larvae are fed once or twice per day cultivated microalgae including *Chaetoceros gracilis*, *Dunaliella tertiolecta*, and *Hymenomonas elongata*. The amount of food is routinely adjusted after microscopic inspection of the shape, pigmentation, and stomach content of larvae (Figure 2). The rearing temperature is kept below 10°C, and time to metamorphosis is approximately 30 days.

Early juveniles

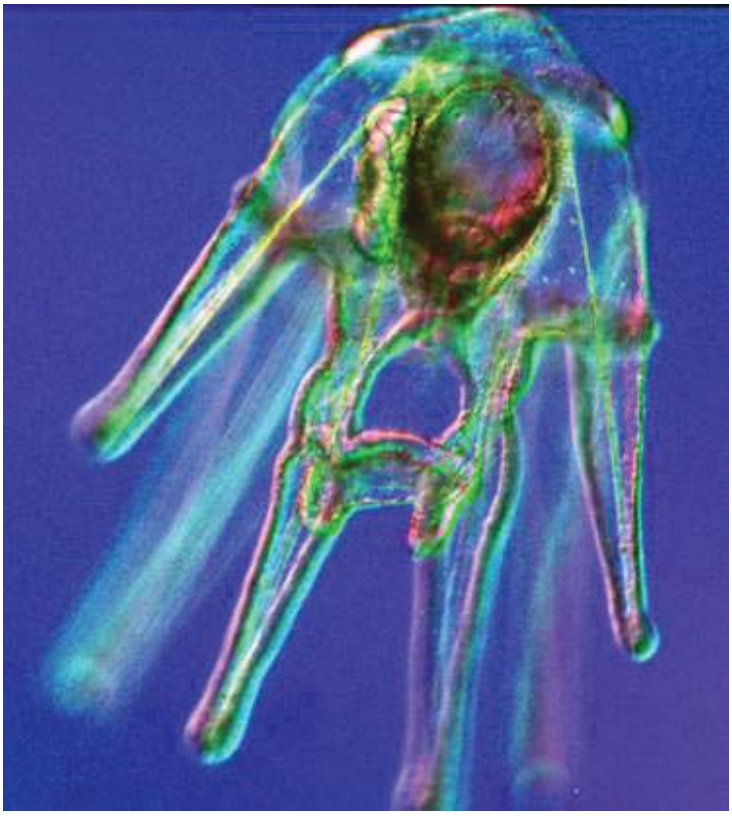

Figure 2
Sea-urchin larva with early juvenile rudiment on the left side of the stomach.

Early juvenile rearing in Bodø is based on the Japanese system[8] where competent larvae are induced to settle on corrugated plastic plates covered with cultivated benthic diatoms that provide the initial food for postlarvae and early juveniles (Figure 3). The growth of diatoms on the settlement plates is controlled by the amount of artificial light from fluorescent light tubes positioned directly above the rearing tanks. Detachment of early juveniles from the plates is facilitated by KCl-induced paralysis.[9]

Early juveniles may require inter-

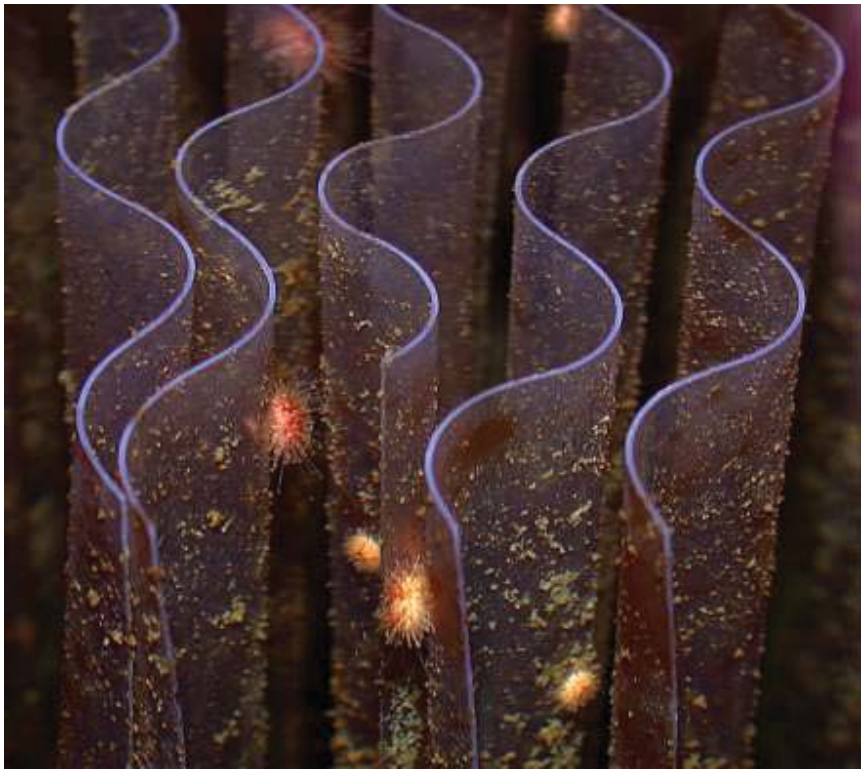

Figure 3
Early sea-urchin juveniles on corrugated settlement plates.

mediate culture and additional feeding with locally available foliose seaweed, such as *Ulva lactuca* or *Palmaria palmata,* before they are ready for transfer to grow-out.

Juvenile Grow-out

Grow-out trials are currently conducted in a variety of experimental containers, as a commercial-scale juvenile grow-out system for sea urchins is not yet available. Both land- and sea-based systems face the dual challenges of maximizing production capacity and minimizing maintenance effort. Juveniles fed fresh kelp may reach harvestable size in approximately 2 to 3 years of grow-out cultivation,[10] and recent trials with a new dry food from NIFA (Figure 4) suggest that the grow-out time may be reduced to less than 2 years.

The gonad index of cultivated sea urchins may be greater than 25%, or approximately twice the average gonad size of urchins harvested from natural populations.[11] Ongoing experiments at HBO are aimed at improving the composition and pigment content of formulated feeds, in an attempt to match the superior colour, consistency, and flavour of gonads from urchins fed fresh kelp.[12]

Figure 4
Experimental production of dry feed pellets for sea urchins.

Gonad Enhancement

Although NIFA had previously developed a moist, formulated feed for sea-urchin gonad enhancement,[13] they have recently amalgamated with the Norwegian Herring Oil and Meal Industry Research Institute, and are now focusing their research on the development of an improved commercial dry feed suitable for both grow-out and gonad enhancement. Feed composition influences both the 'bitter taste' and the 'sweet taste' of sea-urchin gonads. The undesirable bitter taste is associated with increased levels of the amino acid valine, while the desirable sweet taste is associated with increased levels of the amino acids alanine and glycine.[14]

Sea urchins in gonad enhancement trials are prone to increased mortality during the first four weeks after harvest. Controlled experiments have demonstrated that such post-harvest mortality is caused by lack of salt water immersion and rough handling during harvest and transport. Rough handling may also cause non-lethal injuries which lead to reduced gonad growth due to a combination of reduced appetite and lower feed conversion efficiency.[15]

Gonad enhancement in experimental land-based rearing systems has been carried out successfully at sea-urchin densities up to 6 kg^{-2}. [16] Increased mortality and reduced gonad growth at higher stocking density may be due to the fact that adult *S. droebachiensis* has a relatively low tolerance of nitrite[17] and ammonia,[18] because they have a low oxygen requirement (< 0.15 mg min^{-1} kg^{-1} at temperatures < 14°C).[19]

A prototype of a new commercial system for sea-based cultivation of sea urchins is currently being tested in northern Norway (see www.seanest.no). A feed-lot based management scheme for harvesting natural urchin populations is also being evaluated (www.sjomatklynge. no).

Processing

Attempts to operate processing plants for sea urchins in Norway have failed, possibly due to the variable quality and unpredictable supply of sea urchins from natural populations. As a result, wild sea urchins from Norway are now exported whole for processing abroad. This practice greatly increases the risk of accidentally introducing the parasitic nematode *Echinomermella matsi* into new areas. This epizootic parasite was discovered only 30 years ago,[20] and is still not reported outside northern Norway.

Prospects

Sea urchins are short-listed among the candidate species worthy of inclusion in national efforts to diversify the aquaculture industry.[21] Recent developments in dry-food manufacturing and hatchery production may prompt greater national involvement in the strategic development of echiniculture in Norway. A successful echiniculture industry would also benefit sea-urchin harvesters by providing needed access to domestic processing and marketing channels.

References

1. Hagen NT. 1987. Sea urchin outbreaks and nematode epizootics in Vestfjorden, northern Norway. *Sarsia* 72:213-229.
2. Hagen NT. 2003. Nematoden *Echinomermella matsi*. Parasittproblem ved villfangst og

oppfôring av kråkeboller. *HBO-rapport* 7/2003:i-viii, 1-26. [in Norwegian]

3. Hagen NT. 1997. Out-of-season maturation of echinoid broodstock in fixed light regimes. *Bull. Aquacul. Assoc. Canada* 97-1:61.
4. Hagen NT. 1999. Kråkebolleoppdrett i Nord-Norge. *HBO-rapport* 5/1999:1-23. [in Norwegian]
5. Strathmann MF. 1987. Phylum Echinodermata, class Echinoidea. In, *Reproduction and Development of Marine Invertebrates of the Northern Pacific Coast. Data and Methods for the Study of Eggs, Embryos, and Larvae* (MF Strathmann, ed), p. 511-534. University of Washington Press, Seattle.
6. Hagen NT. 2003. Evaluation of electric stimulation as a method for inducing green sea urchins to spawn. In, *Echinoderm Research 2001* (J-P Feral, B David, eds), p. 237-242. A.A. Balkema, Lisse.
7. Hagen NT. 1996. Tagging sea urchins: a new technique for individual identification. *Aquaculture* 139:271-284.
8. Hagen NT. 1996. Echinoculture: from fishery enhancement to closed cycle cultivation. *World Aquacul.* 27(4):6-19.
9. Hagen NT. 2003. KCl induced paralysis facilitates detachment of hatchery reared juvenile green sea urchins, *Strongylocentrotus droebachiensis*. *Aquaculture* 216:155-164.
10. Hagen NT. 2004. Near exponential growth of hatchery reared *Strongylocentrotus droebachiensis*. In, *Sea Urchins: Fisheries and Ecology* (JM Lawrence, O Guzmán, eds), p. 359-365. DEStech Publications, Inc., Lancaster.
11. Hagen NT. 1998. Effect of food availability and body size on out-of-season gonad yield in the green sea urchin, *Strongylocentrotus droebachiensis*. *J. Shellfish Res.* 17:1533-1539.
12. SPIINES2. 2005-2006. Sea urchin production in integrated systems, their nutrition and roe enhancement. *EU-project*.
13. Mortensen A, Siikavuopio SI, Raa J. 2004. Use of transglutaminase to produce a stable sea urchin feed. In, *Sea Urchins: Fisheries and Ecology* (JM Lawrence, O Guzmán, eds), p. 203-212. DEStech Publications, Inc., Lancaster.
14. Dale T, Siikavuopio SI, Aksnes A, Hope B, Gebauer R, Carlehög M. 2006. Smak og struktur på kråkebollegonader. Forholdet mellom biokjemisk sammensetning og produktkvalitet. *Fiskeriforskning Rapport* nr. 4/2006:1-37. [in Norwegian]
15. Dale T, Siikavuopio SI, Aas K. 2005. Roe enhancement in sea urchin: effects of handling during harvest and transport on mortality and gonad growth in *Strongylocentrotus droebachiensis*. *J. Shellfish Res.* 24:1235-1239.
16. Siikavuopio SI, Dale T, Aas K, Mortensen A. 2004. Effekt av individtetthet på overlevelse og gonadevekst hos villfanget kråkebolle (*Strongylocentrotus droebachiensis*) i landbasert oppdrett. *Fiskeriforskning Rapport* nr. 1/2004:1-24. [in Norwegian]
17. Siikavuopio SI, Dale T, Christiansen JS, Nevermo I. 2004. Effects of chronic nitrite exposure on gonad growth in green sea urchin *Strongylocentrotus droebachiensis*. *Aquaculture* 242:357-363.
18. Siikavuopio SI, Dale T, Foss A, Mortensen, A. 2004. Effects of chronic ammonia exposure on gonad growth and survival in green sea urchin *Strongylocentrotus droebachiensis*. *Aquaculture* 242:313-320.
19. Siikavuopio SI, Christiansen JS, Mortensen A. 2002. Vannbehov hos Drøbak-kråkebolle (*Strongylocentrotus droebachiensis*) i oppdrett—effekt av temperatur, kroppsstørrelse og fôring. *Fiskeriforskning Rapport* nr. 10/2002:1-23. [in Norwegian]
20. Jones GM, Hagen NT. 1987. *Echinomermella matsi* sp. n., an endoparasitic nematode from the sea urchin *Strongylocentrotus droebachiensis* in northern Norway. *Sarsia* 72:203-212.
21. Anonymous. 2003. Planmessig igangsetting av nye arter i oppdrett (Evaluation of new aquaculture species). Report commissioned by the Norwegian Department of Fisheries. *KPMG AS, Senter for havbruk og fiskeri, Trondheim*, 309 p. [in Norwegian]

Authors

Nils T. Hagen is a professor of marine aquaculture at the Department of Fisheries and Natural Science, Bodø University College, N-8049 Bodø, Norway (e-mail: Nils.Hagen@hibo.no).

Sten I. Siikavuopio is a senior researcher at the Norwegian Institute of Fisheries and Aquaculture Research, Tromsø N-9291, Norway.