A sea urchin dive fishery managed by exclusive fishing areas

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1. INTRODUCTION

The fishery for the green sea urchin (*Strongylocentrotus droebachiensis*) (Photo 1) presents an opportunity to devolve responsibility for management of a fishery resource. A central consideration in the management of the green sea urchin is to maintain a dynamic equilibrium between the sea urchin population and the kelp beds on which it feeds (Photo 2). The management strategy described here sought to implement this management task by allocation of exclusive fishing grounds to most of the fishing fleet. A small part of the fleet chose not to fish exclusive zones and shared a fishing ground equally and had some control over management of the resource.

Spatial property rights are an old approach to fishery management. The inspiration for exclusive fishing zones described here came from Johannes' (1978) description of a reef and lagoon tenure of fishing rights in the South Pacific. Ruddle (1988) described the long history of community management in Japan, and Kurian (1999) described similar institutions in India. More recent examples have been described for Chile (Castilla *et*

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PHOTO 1
Urchins on kelp

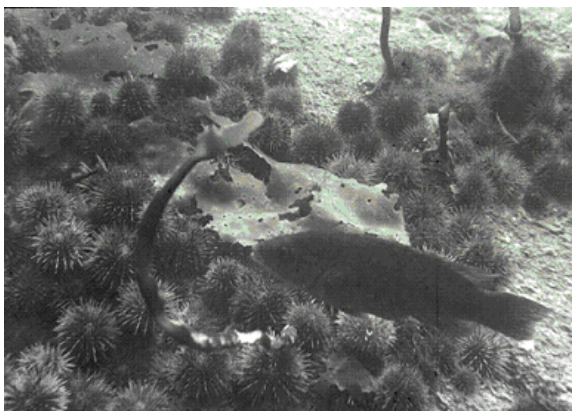

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PHOTO 2
A sea urchin feeding front that has nearly consumed the kelp plants at the front. Bare rock is located to the right and dense kelp to the left

al., 1998), Mexico (Miller, 1989), and the South Pacific (Viswanathan, 1999). Reports of community spatial rights are much more common that individual spatial rights.

Most of the Nova Scotia green sea urchin fishery has been brought under a habitat-based regime. Individual fishers had exclusive access to a fishing area and were given responsibility to manage the stock in their area. Habitat-based management can be considered as an intermediate step in a continuum of fisheries management categorized by the degree of habitat control. Specifically:

i. *Stock-based Management* manages within the natural habitat carrying capacity to address problems of growth overfishing, recruit overfishing, and wasteful fishing practices such as discarding. Typically, catch and/or fishing effort are controlled.
ii. *Sea Ranching* grows and releases early life history stages to more fully use the habitat carrying capacity for later life history stages. This is intended to overcome bottlenecks of low spawning stock or loss of juvenile habitat (Travis, Coleman and Grimes, 1998).
iii. *Habitat-based Management* opens production bottlenecks by manipulating the balance between the target species and its resources (e.g. physical habitat or prey).
iv. *Aquaculture* spans a wide spectrum of habitat control from adding artificial habitat (e.g. mussel culture in the sea) to housing and feeding all life history stages in man-made facilities (e.g. trout culture).

The Nova Scotia sea urchin resource is well suited to habitat-based management. The sea urchin and its principal food, kelp (a category of large brown sea weeds), are abundant, but not optimally distributed for high sea-urchin fishery yield (Wharton and Mann, 1981; Miller, 1985; Scheibling, 1986). Much of the sea urchin stock is of no commercial value because the sea urchins have removed most of the kelp, the urchins are poorly fed, and the gonads poorly developed (Fletcher, Pepper and Kean, 1974; Keats, Steele and South, 1984; Meidel and Scheibling, 1998; Wahle and Peckham, 1999). Sea urchins congregate in dense feeding fronts at the deep edge of kelp beds and most harvesting occurs at these fronts. The low motility of sea urchins (Garnick, 1978; Scheibling, Hennigar and Balch, 1999; Dumont, Himmelman and Russel, 2004) and nature of kelp make them well suited for manipulation. The abrupt changes of habitat and sea urchin abundance on a scale of metres make it more suitable for in situ management by a harvester than remote management on a large scale by a bureaucracy. As a dive fishery, the results of harvesting and enhancement are visible to the fisher, unlike most fisheries where perceptions of the state of the stock are clouded by selectivity of the fishing gear.

2. THE FISHERY[1]

The Nova Scotia sea urchin fishery is located on the outer Atlantic coast from Shelburne to Cape Breton Counties, plus Digby County at the mouth of the Bay of Fundy (Figure 1). Capture is by diving only. Although called a roe fishery, gonads of both sexes are marketed.

The market is almost entirely in Japan. When the prices were highest, the best quality sea urchins were shipped live by air to Japan, but most roe extraction was carried out in Nova Scotia and Maine. Of the several processing plants in Nova Scotia that attempted roe extraction, only one survived more than a few years. After 1997, processors in Maine purchased most of the Nova Scotia harvest.

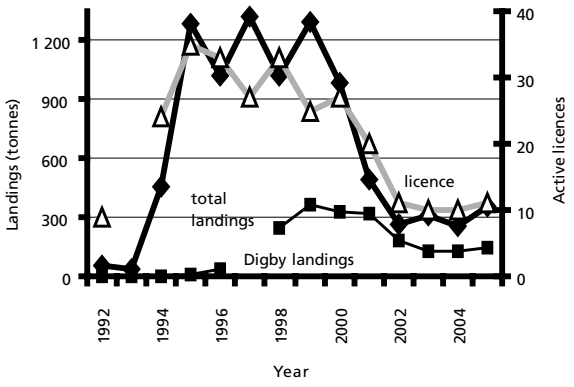
Landings first exceeded 100 tonnes in 1994 and peaked at 1 300 tonnes in 1997 (Figure 2). Beginning in 1994, an amoeboid disease spread in both directions from

[1] The author has been conducting research on this fishery since 1991, and much of the descriptive and historical material is drawn from that experience.

western Halifax County until all the stock within diving depths was eliminated from Shelburne through Richmond Counties by 2002. Cape Breton and Digby Counties were unaffected (Scheibling and Hennigar, 1997; Miller and Nolan, 2000; author's pers. obs.; urchin harvesters pers. comm.). The decrease in active licences followed this trend (Figure 2). Stock recovery had begun in parts of Shelburne and Halifax Counties by 2005.

FIGURE 1
Nova Scotia counties referred to in text

FIGURE 2
Total annual Nova Scotia sea urchin landings, annual landings from Digby County and number of active licences



Some of the usual sea urchin stock assessment and management methods are expensive and of uncertain value. Diver surveys of biomass are slow and expensive. Nutritional state and seasonal cycle affect gonad size (Himmelman, 1978) and hence sea urchin marketability. This varies on a small spatial and temporal scale (Keats, Steele and South, 1984), which makes it difficult for a management agency to monitor. Predicting recruitment to legal size is also difficult, because growth rate varies on a small spatial scale (Robinson and MacIntyre, 1997; Vadas *et al*., 2002). Unknown stock-recruit relationships preclude making an informed choice of spawning stock biomass. Catch rate has been shown to be an unreliable indicator of stock size in many dive fisheries (Prince and Hilborn, 1998). If a biological basis for setting catch quotas can be found, they can be expensive to generate, administer and enforce.

Competing for catch can have undesirable social and economic consequences. Time spent hunting for commercially viable beds adds to the cost of fishing. Fishers lose incentive to schedule harvests for times of high prices or high gonad yields because another fisher can harvest them first. Conflict can result when one fisher harvests a bed first found by another. Under a common property management regime, the lack of agreement and cooperation is an obstacle to decision-making about efficient harvest and resource use.

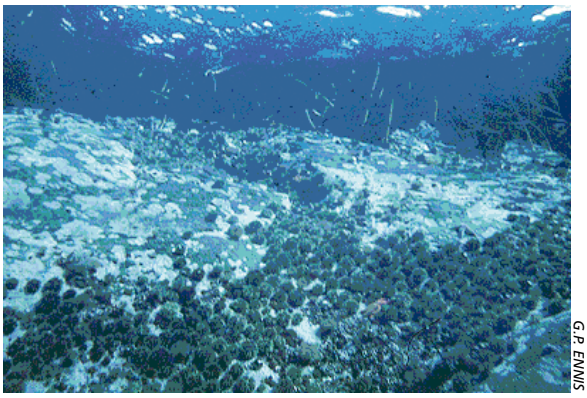
Several entrepreneurs attempted to move beyond habitat-based management into "feedlot" aquaculture, but unsuccessfully. One operation fenced urchins on a smooth bedrock bottom in the sea, but the location was too wave-exposed (Photo 3) and the sea urchins were scattered. About ten other operations collected commercial sized sea urchins with sub-commercial sized roe, placed them in wire cages, and added kelp for food. The labour cost of collecting and adding kelp was high and in some locations wave action destroyed the sea urchins. Confinement in cages removed the sea urchins' ability to seek shelter.

3. MANAGEMENT REGIME

3.1 Initial management, 1991–1999

Fishery regulations evolved from 1991 through 1999. Initially, any commercial fisher could obtain a sea urchin licence. Next, applicants were limited to participants from

PHOTO 3
An aggregation of sea urchins unable to reach kelp located in shallow water because of wave turbulence



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the recently collapsed groundfish fishery. By 1995, successful applicants were chosen by draw from a large pool of interested commercial fishers. There could be only one licence a boat. To control effort and promote diver safety, each licence was allowed a maximum of four divers. An exploratory licence holder had to provide proof of sale of two tonnes of sea urchins the first year and 4 tonnes in subsequent years to maintain a licence. After being active for three years, an exploratory licence could convert to a permanent licence. A permanent licence required no minimum landing and could be transferred to another fisher. The minimum legal size was 50 mm test diameter and urchins culled from the catch had to be discarded on the fishing ground. Seasons initially corresponded to the months of best roe yield, but this restriction was removed when fishers demonstrated that dates of beginning and end of acceptable roe size could change abruptly on a small spatial scale and from year to year.

Fishery monitoring was entirely from catch records and from personal communication with fishers and buyers. Mandatory catch records with daily landed weight and prices for each fisher were initially supplied from buyers' sales slips. Beginning in 1997, fishers were required to hire a commercial monitoring company to enter their daily catch record and fishing location on a government database. For 20 percent of fishing trips, a monitoring company representative met the boat to verify that the landed catch was reported correctly. Data from both types of reporting suffered from lack of quality control. Under reports from buyers, not all catch records were submitted. Under commercial monitoring, fishers were asked to buy a service they did not want, the commercial firms serviced a database they did not use, and the government branch that administered the database also made minimal use of the data. Better data on landings, diver hours, detailed fishing location, and percent roe yield were obtained in volunteer logbooks from most fishers from 1994 to 2000. Frequent reminders to fishers and feedback with data summaries were needed to maintain this source.

Licence holders formed organizations in Guysborough, Halifax, Shelburne, and Digby Counties. Each group used peer pressure to moderately improve the adherence to regulations and made constructive contributions to formulating some rules. However, their strongest actions were reserved for lobbying senior government officials when they disagreed with the fishery manager and scientist assigned to their fishery. Their level of cooperation with the management agency reflected the personalities of their leaders.

In 1995–96, licensees and their divers developed diver safety guidelines. Because few of the licence holders were divers, some lacked appreciation for the hazards of winter diving and made unreasonable requests of their divers. The guidelines were practical and generally supported. An exception to support was in Digby County where strong currents, fog, and depth of fishing made it the most hazardous place to dive. The fishery's only fatality occurred there.

Initially, licence holders fished competitively and were each limited to one of three large areas. By 1994, each fisher was limited to one of 10 smaller areas, usually adjacent

to one county. This restriction reduced concentration of fishing effort and responded to complaints that harvesters from outside the local area were taking a local resource. Under certain conditions, a fisher could fish his own exclusive area called a restricted zone. Except for Digby County, all fishers that were permitted to apply for a restricted zone did so.

In Digby County, two fishing areas provided the best catches and the most shelter from ocean swells. Because the five licence holders could not agree on dividing these preferred areas into restricted zones, they first set a short fishing season for the preferred areas. They later changed this to a maximum number of fishing days for each boat within a longer season.

3.2 Restricted zones

After a year of many public meetings and one-on-one discussions, a new management plan including restricted zones was approved in 1995. The licence conditions for a zone were:

i. only one licensee could fish in a zone and he could not fish outside it;
ii. the zone applied to no fishery other than sea urchins;
iii. the licensee must enhance the resource productivity in the zone; and
iv. after a trial period of four years, an audit of compliance with the enhancement requirement would be carried out.

Legal authority for zones was found in the *1985 Canada Fisheries Act*. This act provides for many types of management areas that can be used to regulate catch and fishing locations. Urchin zones were an extension of this provision that limited fishing in an area to one licence. Although not unique to this fishery, an owner-operator policy also limited each fisher to one licence.

The one-fisher/one-zone concept strongly diverged from tradition among coastal fishers. Typically, fishers are hunters who like the option to seek their prey wherever it occurs, as well as competitors who take pride in a reputation of community highliner. They also expect the opportunity of returning to port with a saleable catch nearly every time out and do not dedicate days to resource enhancement.

During planning meetings, licensees were asked to propose zone boundaries no larger than they could manage and to attempt to resolve overlapping borders with other fishers. The proposal to introduce zones created bedlam for several months both in and out of the urchin fishery. In Guysborough County, the most lucrative fishing area, a group of eight licensees lobbied three levels of elected officials plus senior bureaucrats with the argument that the county urchin resource was only large enough to be divided among themselves. During this time, the author quickly surveyed the county in order to negotiate boundaries. Nine zones were negotiated in Guysborough that year. Two years later there were 14 zones, with room for several more.

In Shelburne County, no fisher applied for a restricted zone in 1995, but six fishers negotiated an informal agreement to remain in separate fishing areas. This agreement failed on the first day of the season, when four of the six chose to fish on the same shoal. After a year of conflict over fishing areas, all six asked for zones for the next fishing year. Borders were settled amicably except for one overlap of about 200 m of shoreline. After two weeks of negotiation failed, the parties agreed to binding arbitration.

Two groups strongly objected to the zone concept. First, chiefs of 13 Nova Scotia First Nation bands objected on the grounds that private ownership of fishery resources was contrary to their traditions. They recommended another type of property right, transferable quotas. Second, fishers in communities near the fishing grounds who did not obtain sea urchin licences objected on the grounds that restricted zones were non-traditional and that new applicants should not be permanently excluded from the fishery.

By late 1997, boundaries of 26 zones had been negotiated and a few others denied. A requirement that new applicants for zones must have harvested 25 t/yr was added

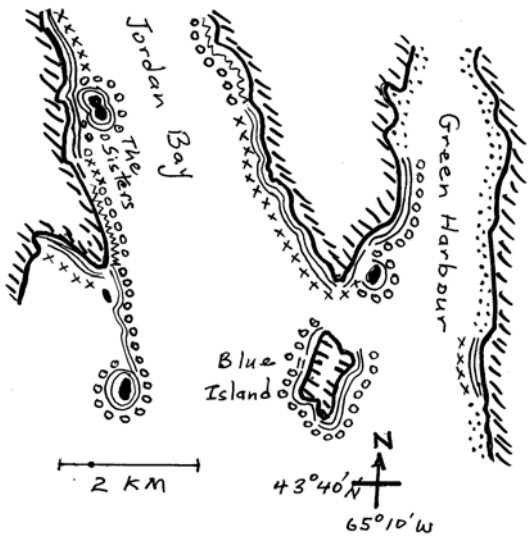
to demonstrate competence in this fishery. Fishers were often assigned a zone larger than they could manage (with one vessel and four divers) to overcome their apprehensions about confinement to a single area. However, this created the need for later realignment.

Only a few fishers were successful in stock enhancement activities, i.e. bringing more of the stock up to marketable quality. These activities included: collecting under-fed sea urchins from areas of over-abundance and dumping them offshore to allow seaweed to recover from sea urchin grazing; moving under-fed sea urchins to kelp; and moving kelp to under-fed sea urchins. A financial grant to develop sea urchin stock enhancement methods was offered to an organization of coastal fishers, only a few of whom were licensed to fish sea urchins. Not only did the organization refuse the grant, it also strongly objected to anyone receiving the grant on the grounds that sea urchin abundance might be increased and thereby negatively affect other species of interest to the organization. However, the grant was given to one fisher (Mr Allan Baker), who was very successful in developing enhancement methods, and he willingly shared results with other interested parties. Because fishers with zones were not competing for catch, the usual barriers to communication were removed.

A second requirement of zone-holders was more successful. They were asked to provide a detailed map of the sea urchin and seaweed distribution along shore. This was to insure that they knew the resource in their zone well enough to develop a harvest plan. The biologist could check the accuracy of the maps from prior knowledge of each zone or could make spot checks in the field. Nearly all harvesters admitted finding new urchin beds and most maps were well done.

Figure 3 is an example of such a map. The following conclusions may be drawn from the map and annotations. On the west side of Blue Island and around the small island at the mouth of Green Harbour, urchins have reduced the kelp bed to a shallow fringe. Immediate harvesting is needed before all the kelp is eliminated and the sea urchins are without food to build roe. On much of the shore, urchins were too small and would be of no value for a few years. If the zone included areas with large but underfed urchins, these urchins could be moved to under-populated zones to feed on abundant kelp. Much of Blue Island and the shoal to the west is exposed to ocean swells and can be harvested on only calm days. The more sheltered areas inside Jordan Bay near The Sisters should be reserved for harvest on stormy days when outer areas are inaccessible. About 12 km of feeding front are available for harvesting.

FIGURE 3
Map of most of one sea urchin fishing zone in Shelburne County



Symbols show kelp and sea urchin distribution: ooo-harvestable sea urchin feeding front, xxx-sea urchins too small for harvest, single line-deep edge of kelp bed <3 m, double line-deep edge of kelp bed 3-6 m, wavy line-deep edge of kelp bed >6 m, stipple-bottom unsuitable for kelp or sea urchins (mud, sand, or loose cobble).

By 1999, the first 14 recipients of zones had completed the four-year trial period. Industry and government representatives jointly developed audit criteria based on the length and depth of sea urchin feeding fronts. The important criteria (i.e. decision rules) were:

i. All feeding fronts included in the audit had sea urchins of commercial densities. (An experienced commercial sea urchin diver participating in the audits made this judgment.)
ii. Unmanaged fronts were defined as locations where dense kelp extended

from the low tide line to less than 6 m depth, in areas where the bottom was capable of supporting kelp to that depth. (Kelp beds ending at less than 6 m deep are at risk of being eliminated by sea urchin grazing.)

iii. If greater than 1 000 m of unmanaged front was found in a zone, new borders would be negotiated to bring the total under 1 000 m.

Only one of the 14 zones met the criteria for being well managed, i.e. less than 1 000 m of front at less than 6 m depth. All but two zones also had more than 1 000 m of front at less than 4 m depth. For the 14 zones combined, the total front at less than 6 m and 4 m were 281 km and 192 km respectively. Using the method discussed by Miller and Nolan (2000), it was determined that the total length of front fished by 14 fishers in one season at all depths was 89 km. Thus, they were fishing only a small portion of their zones.

3.3 Licence fees

Licence fees to participate in the sea urchin fishery consist of:

Fisher's Registration Card	Can$50.
Vessel Registration Card	Can$50
Sea Urchin Licence	Can$100.

The fishers' registration card would be required of all divers (2 – 4) on a boat. Only one of the fishers' associations levied fees and this lasted for only a few years. The fees paid by each fisherman would have been on the order of Can$200/yr.

3.4 Failures

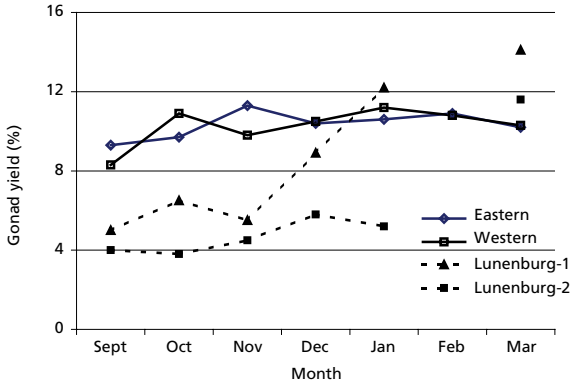
Negotiations to establish the habitat-based regime were acrimonious, but may have been unavoidable because this approach differed so much from traditional fishing practices. The level of underutilization of most of the audited zones indicates areal high-grading. Probably, only the areas most accessible or with the best roe yields were fished. We expected the percentage roe yield to increase with time as a result of enhancement activities. However, most plots of mean annual gonad yields for 13 fishers for which we have 4 or 5 years of records showed only modest or no improvement. From a starting mean yield of about 10 percent, three increased more than 3 percent, one by 2 percent, two decreased about 2 percent, and the remainder changed by 1 percent or less.

Fishers whose zones were audited were unwilling to relinquish a portion even when it was clear much of the stock was unfished. The terms of the audit were negotiated between DFO and zone holders, and the management plan called for a review of zones after four years. But prior to the audit, some zone holders realized they would loose a large portion of their zones under the negotiated criteria. They convinced fishery managers that they had not understood the negotiated terms, even though these negotiations occurred over a period of months with detailed minutes circulated at intervals. The fishery managers did not participate in resource surveys or observe sea urchin fishing and did not accept advice from those who had. They deferred to the arguments of the fishers. The audit results were never applied, and sea urchin resource worth several million dollars was left unharvested and died of disease in 1999–2001. Licences promised to new entrants to the fishery following the four-year trial period were not made available.

3.5 Successes

The benefits of zones are not easily quantified, because most were not fully exploited. Most fishing areas without zones, which might serve as the control areas, were scarcely fished. Digby County was the exception as an unzoned area consistently fished. Catches there declined from 362 to 125 tonnes over four years (Figure 2) even though there was no disease. Total catches from zones in Halifax and Shelburne Counties ranged from

FIGURE 4
Mean gonad yield for months the fishery was operating in 1998–99



Open diamonds and squares represent the fishery in Halifax plus Guysborough Counties and Shelburne County respectively. Closed triangles and squares represent feeding fronts at each of two locations in Lunenburg County (Meidel and Scheibling 1998).

835 to 1 140 tonnes with no trend over time for the four years from 1995 to 1998 before the major impact of disease.

The zone maps of sea urchins and kelp were successful. They provided harvesters with information to develop a harvest plan, including the distribution of the resource and identification of areas that did and did not need enhancement.

By knowing their fishing grounds, fishers were able to maintain gonad yields at commercially-acceptable levels, in spite of wider fluctuations in yields during the harvest season. In eastern Canada, the green sea urchin typically spawns in April and then gradually rebuilds its gonads to a peak size in March (Miller and Mann, 1973; Himmelman, 1978; Meidel and Scheibling, 1998). Figure 4 gives the monthly mean yield values taken by the fishery in Halifax plus Guysborough Counties and Shelburne County in the 1998–99 season. This is compared to the more variable monthly means from two feeding fronts located in Lunenburg County between these fishing areas (Meidel and Scheibling, 1998).

Because fishermen did not compete for resource, they could target high prices and save time searching for resource. At times of low prices, they sometimes refused to sell at all, which they could do without fear of losing their stock to another fisher. The opening of the Maine fishery in October 2006 depressed the Nova Scotia price to US$1.40/kg and fishers stopped harvesting. By Christmas, prices recovered to US$2.20/kg and fishing resumed (Garland, fisherman, pers. comm., 2007). Zones also gave fishers at least one-third more fishing days, because they spent less time searching for sea urchins and they could reserve sheltered areas for stormy days (Baker, Giroux, and Garland, fishermen, pers. comm., 2007).

Some of the usual resource management costs were eliminated. Enforcing regulations was not a problem. Fishermen policed their own borders and regulations were kept to a minimum. Initially a few misunderstandings over the location of boundaries were resolved by negotiation. Only one violation for fishing illegally in a zone occurred over six years. Without catch quotas or quota monitoring, the incentive to misreport landings was reduced. Except for initial zone allocations, the assessment costs were low. Fishers paid for the zone audits following the four-year trial period. Audit criteria based on length and depth of feeding fronts were easy to survey. Zone holders were adamant that zones were beneficial, and no fisher asked to give up the allotted zone to re-enter the competitive fishery. With the exception of one county, the fleet had a good diver safety record with a high awareness of safety issues.

4. DISCUSSION

The habitat-based management regime was economically successful and increased profits of participants and reduced costs of fishing and resource management. The social success was more equivocal. Participants were pleased to have zones, but prospective new entrants, who were promised zones, were not accommodated and the resource was under-harvested. Biological sustainability was not adequately tested because the resource died of disease after 3–5 years under the plan.

Prince *et al.* (1998) discussed issues for an abalone dive fishery similar to those encountered for the sea urchin fishery. Abalones are highly aggregated with variable

growth and mortality on a small spatial scale. Because a management agency cannot afford to assess or regulate a fishery on such a small scale, they proposed that exclusive fishing areas be assigned to individuals or small groups. However, they found many fishers unwilling to relinquish their right to roam or to accept stock management responsibilities. They also found making the area allocations a daunting task. In the sea urchin fishery, fishers were given the choice of choosing a zone or not. This choice was easier than for the abalone fishery, because existing sea urchin licences were fewer than necessary to fish the entire resource.

A few important changes could improve the habitat-based management regime. Although zone holders were keen to eliminate competition through exclusive access, they were less keen to work to improve resource yields. Therefore, rules are needed to require resource enhancement. Eligibility criteria for obtaining a zone should be described in detail. When fishers apply for a zone, they and the management agency could sign a contract that includes the responsibilities of both parties for the duration of the contract, the details of the audit and the consequences of not meeting audit criteria for a well-managed zone. So that a fisher would not hold a zone while not fishing and denying access to others, a minimum annual landing should be required. A contingency plan for loss of the resource to disease should be included, e.g. exclusive zones would be eliminated and reallocated to participants after the resource recovered. These changes should reduce acrimonious negotiations for issuing and downsizing zones.

The objective of areal sea urchin management is to create a fishery with individual fisher-managers responsible for a zone large enough to support a single vessel and with incentives to use habitat-based management of their resource. The costs of regulation and fishing are reduced and the yield can be enhanced. Matching fishers to area included unusual problems. In most regulated fisheries, the fleet fishing power is in excess of what is needed to harvest the resource and regulations restrict the effort (e.g. with limits on catch, seasons, or gear). In the one-area/one-boat urchin fishery with few regulations, the balance must include enough effort as well as not too much effort. Because some fishers fish harder than others, and because environmental differences make some areas easier to fish than others, the required sizes of area varies. Therefore, one needs an empirical measure of how completely an area is fished; this was the intent of the zone audits. Given exclusive access, the fisher will hopefully not overexploit the resource. Because the amoeboid disease largely eliminated the stocks in 1999–2001, this experiment has not generated a sufficient time series to adequately assess the long term effect of the programme.

Conflicts arose over the spatial allocations, because many fishers viewed allocations as a competition to obtain as large an area as possible and then believed that they had earned a right to retain it. Also, fishers without sea urchin licences viewed zones as a threat to their future access. Finally, the radical departure from 300 years of fishing tradition and 100 years of fishery management tradition presented fishers and the regulators with unfamiliar and uncomfortable problems.

5. ACKNOWLEDGEMENTS

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