Territorial user's rights and the Australian abalone (*Haliotis* sp.) fishery

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Abstract: On the basis of the Australian experience with the research and management of abalone (*Haliotis* sp.) stocks and our wider experience of fisheries research and management, we argue that the spatial scale of an exploited species should be an important determinant in developing management strategies for any exploited species. The small spatial scale of functional units of abalone stock together with their high level of variability between populations and the "law of the commons" context of the Australian abalone fishery combine to undermine the effectiveness of modern broad-acre management tools such as size limits, closures, limited entry, and individual transferable quotas (ITQs). Despite the sophistication of current management regimes, component units of stock can still be sequentially overexploited because the spatial scale of functional units of stock within the fishery is smaller than the effective scale of management. The "tragedy of the commons" and a "tyranny of scale" renders the existing sophisticated system of management suboptimal for this valuable renewable resource. We suggest that management through territorial user rights would enable individual fishers or small communities of fishers to adjust the scale of management to the small scale appropriate to the species. The difficulty of changing management in this way is discussed.

Résumé : À partir de l'expérience australienne en recherche et en gestion des stocks d'ormeau (*Haliotis* sp.) et de notre expérience plus large de la recherche et de la gestion des pêches, nous posons que l'échelle spatiale d'une espèce exploitée doit être un élément déterminant dans l'élaboration de stratégies de gestion pour une espèce exploitée. La petite échelle spatiale des unités fonctionnelles des stocks d'ormeau et leur niveau élevé de variabilité entre populations ainsi que le contexte de « propriété commune » de la pêche de ce mollusque en Australie se combinent pour miner l'efficacité des outils modernes de gestion à grande échelle comme les limites de taille, les fermetures, l'accès limité et les quotas individuels transférables (QIT). Malgré le raffinement des régimes actuels de gestion, certaines composantes des stocks peuvent se trouver encore surexploitées de façon suivie car l'échelle spatiale des unités fonctionnelles de stock dans la pêcherie est plus petite que l'échelle effective de gestion. La « tragédie de la propriété commune » et une « tyrannie de l'échelle » rendent suboptimal le système actuel complexe de gestion de cette précieuse ressource renouvelable. Nous suggérons d'avoir recours à des droits territoriaux d'exploitation, régime de gestion qui permettrait à des pêcheurs, ou à de petites communautés de pêcheurs, d'ajuster leur intervention à la petite échelle convenant à cette espèce. Nous analysons les difficultés suscitées par un tel changement dans la gestion.
[Traduit par la Rédaction]

Introduction

During the twentieth century fisheries science and management developed rapidly. Before the turn of the century, it was argued that humans would never be able to impact the great fish stocks (Safina 1995). However, by early this century, Russell (1931) was using yield per recruit analysis to theoretically consider the overfishing problem of the North Sea and to argue in support of introducing minimum mesh sizes to the North Sea trawl fishery. Assuming constant recruitment to a uniformly growing stock, yield per recruit analyses estimate the optimal size of capture and by the middle of the century legal minimum size limits were commonly applied to fisheries to maximize yields (Cushing 1968; Hancock 1979). During the second half of the century the technologies developed for war (e.g., radar, acoustics, hydraulics, global position systems) were applied to harvesting marine resources and the impact of fishing on recruitment became evident. Ricker (1954) focused attention on the relationship between the abundance of breeding stock and the level of future recruitment to a fishery.

Hardin (1968) described the "tragedy of the commons" by which "each man is locked into a system that compels him to increase his herd without limit in a world that is limited." He noted that "freedom in a commons brings ruin to all" and described its application to the human use of a wide range of renewable resources, including fisheries. During the 1960's and 1970's managers increasingly moved to control fishing power by limiting entry to fisheries and the amount of fishing gear used by each entrant (Hancock 1979). Limited entry denied the general community the right to catch fish for commercial gain, reserving this right for a limited number of licenced commercial fishers, thus, theoretically at least, solving the tragedy of the commons for fisheries.

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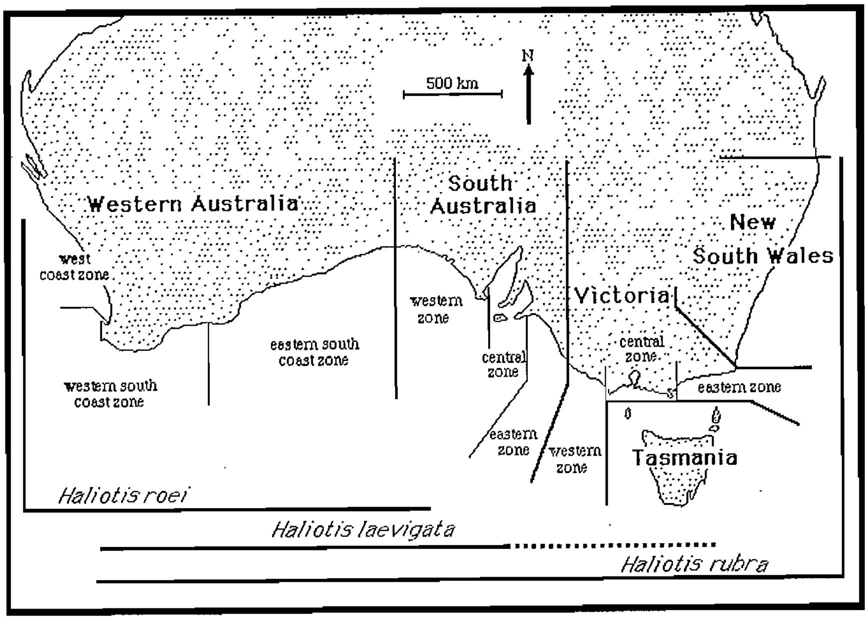
Fig. 1. The five southern Australian states with their abalone management zones, and the geographic range of the three commercially exploited abalone species (from Prince and Shepherd 1992).



By the 1980's fisheries managers were commonly controlling the size of fish caught, the number of participants, the number and size of vessels, the amount and specifications of fishing gear, and the areas and times fished (Bourne 1986; Harrison 1986). However, a seemingly inevitable upward creep of fishing pressure within limited-entry fisheries (Morgan 1980; Harrison 1986; Robins and Sachse 1994) was widely recognized prompting a move towards directly controlling total landings with catch quotas, often individually transferable quotas (ITQs). In some fisheries ITQs have been applied over existing layers of management so that the size of fish caught, the application of fishing effort, and the quantity of catch can all be controlled by legislation (e.g., Prince and Shepherd 1992).

In this paper, it is argued that for some fished stocks even this sophisticated level of management is inadequate for optimizing the management. When the spatial scale of management and monitoring is larger than the scale of the managed populations, fisheries will remain vulnerable to localized overfishing and ongoing population collapses. This argument is supported by a case study of the Australian experience with the research and management of abalone stocks. However, our wider fisheries experience suggests that the issue is relevant to many other fisheries, particularly sedentary invertebrate species and dive fisheries.

Abalone

Abalone are large marine molluscs that form aggregations on shallow inshore reefs (Shepherd 1986; Shepherd and Godoy 1989) where they are easily accessible to collection by commercial and amateur divers. The Japanese and Chinese consider abalone a delicacy and the market price is set in Asia (Rudd 1994). Worldwide abalone stocks form the lucrative basis of high value – low volume dive or littoral collection fisheries.

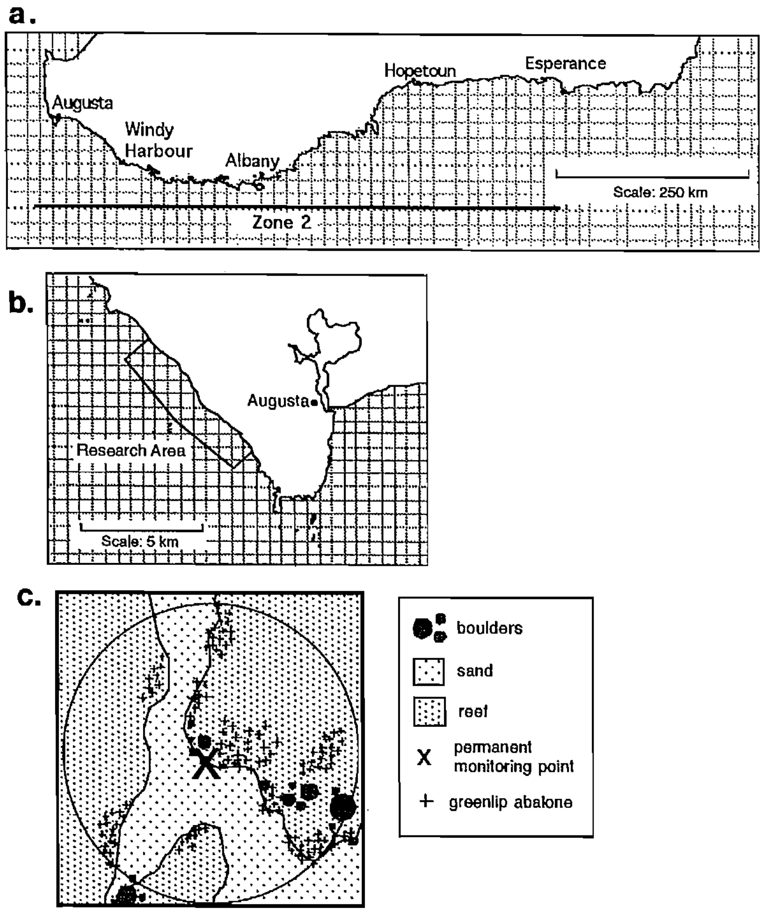
World production of abalone peaked in the late 1960's at approximately 27 600 $t \cdot yr^{-1}$. However, since that peak, catches from the large Californian and Mexican abalone fisheries collapsed (Tegner 1989; Guzmán del Próo 1992), Japanese catches continued to slowly decline (FAO 1973–1988), and quota reductions occurred in Australia (Prince and Shepherd 1992). By the late 1980's global production declined to around 12 000 $t \cdot yr^{-1}$. The real value of abalone increased steadily during the last three decades reflecting declining supply and growing demand in Asia (Rudd 1994). Australia's annual production of about 5000–6000 $t \cdot yr^{-1}$ and Japan's of around 3000–4000 $t \cdot yr^{-1}$ currently dominate global production figures (FAO 1973–1988).

Australian abalone management

Australia's recorded abalone exports are annually worth approximately A$120 million and by value abalone is about 8% of Australia's fish production (Kailola et al. 1993). Three species of abalone are harvested by commercial divers using surface supplied compressed air diving equipment across the five southern states of Australia (Fig. 1). Each state within the Commonwealth of Australia has jurisdiction for the abalone resource within its waters but despite the different jurisdictions management regimes in each state have evolved along similar lines. For a detailed account of each fishery the reader is referred to Prince and Shepherd (1992).

In Australia, the modern fishery began in the early 1960's when compressed air diving equipment became commercially available. By the mid-1960's most states had imposed minimum size limits around the size of first maturity. During the late 1960's catches increased rapidly and a catch in excess of 8000 t was reported in 1968. Most states moved to limit entry to their abalone fisheries during the late 1960's and early

Fig. 2. Maps illustrating the three spatial scales used to map *H. laevigata* in southwest Western Australia. (*a*) Zone 2 of the Western Australian abalone fishery showing the grid used to record commercial catch data. (*b*) The Augusta area showing the grid used to map the productivity of abalone beds in the area. (*c*) A 20-m diameter survey site showing an indicative distribution of *H. laevigata*.



1970's, capping the number of commercial abalone divers at approximately 345 licenced abalone divers across Australia.

At first abalone diving licences were nontransferable; retiring divers relinquished their licences and they were reallocated according to government-maintained waiting lists. However, few divers retired and reported annual catches slowly declined to around 5000 t by 1975. In 1974 the state authorities began to allow the sale of diving licences (Harrison 1986). Abalone divers were allowed to retire from the fishery by nominating a replacement diver and transferring their licence to them. The introduction of licence transferability promoted a further and rapid expansion of landings as new entrants tended to fish harder than the divers they replaced. Between 1975 and 1985 recorded annual catches steadily increased to a peak of approximately 8200 t.

Once again concern at rising catches prompted the authorities to act, introducing individually transferable quota systems during the mid-1980's. After the implementation of ITQs the total allowable commercial catches (TACCs) were generally reduced with industry support. In Tasmania, against the advice of the state fisheries agency, the industry lobbied the government for an overall TACC reduction of 40%. Australia-wide TACCs were around 6000 t by the early 1990's. The TACCs are nominally reviewed annually and most states administer them within 2–3 separate zones each encompassing 100–1000 km of coastline.

Most states also sanction the occasional fishing of "stunted stocks" with otherwise sublegal minimum size limits. This special fishing of stunted stocks is sanctioned on specific days within prescribed areas.

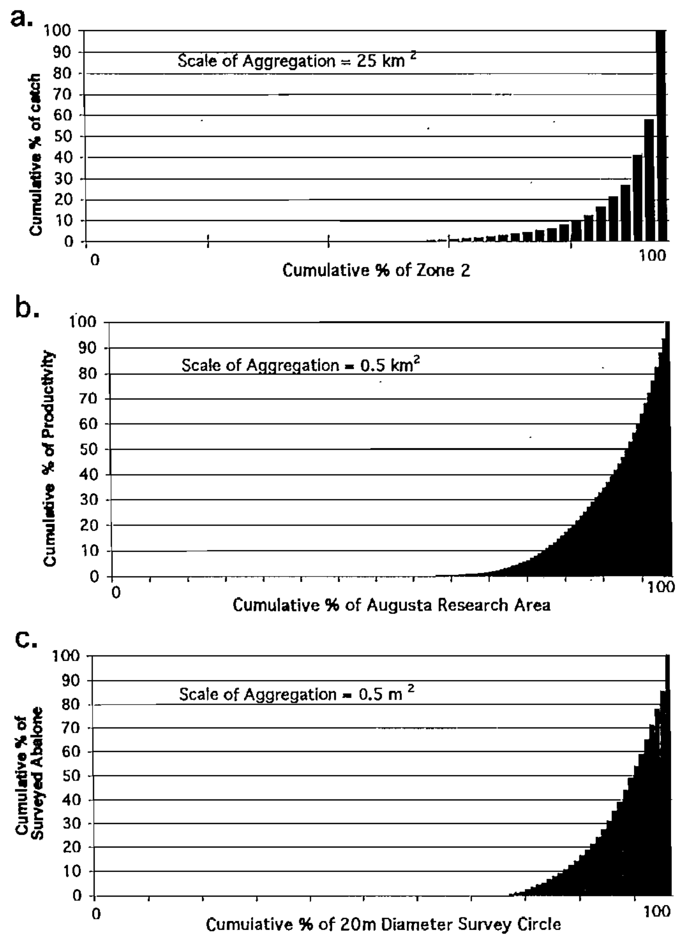
Current understanding of abalone fisheries biology

During the late 1970's and early 1980's as abalone catches rose there was widespread concern about the sustainability of the abalone industry in Australia. The Commonwealth Fishing Industry Research Trust Account responded by supporting parallel research programs into abalone fisheries biology in South Australia, New South Wales, Victoria, and Tasmania. Together these programs of research concluded that a number of factors make abalone stocks difficult to assess and susceptible to overfishing (Prince and Shepherd 1992).

Highly aggregated populations

Abalone are not dispersed through the environments they inhabit; rather they occur in highly concentrated "nuggets" of stock. Three spatial scales used for mapping abalone populations (*Haliotis laevigata*) in southwest Western Australia are

Fig. 3. The spatial distribution of abalone at three scales within Zone 2 of the Western Australian abalone fishery. (*a*) Commercial catch data from the entire Zone 2, scale of aggregation: 25 km. (*b*) Productivity in the Augusta area as reported by commercial divers, scale of aggregation: 0.5 km. (*c*) Distribution of abalone within a single 20-m diameter survey site as measured by scientific divers, scale of aggregation: 0.5 m.



illustrated in Fig. 2: (*i*) the commercial catch statistics aggregated over 10–50 km, (*ii*) the productivity of abalone beds mapped by commercial divers within a research area 8 × 1.5 km, and (*iii*) the location of individual abalone mapped within surveyed circles of 10 m radii.

At all three spatial scales 80% of the abalone are concentrated within 20% of the potential habitat (Fig. 3). In Fig. 4, a similar distribution pattern is shown for *H. rubra* on George III Rock in southeast Tasmania determined using Leslie estimates of 26 cells of equal area (Prince 1989*a*). Approximately 70% of the population was found to be concentrated in 20% of the area. This repeated density profile over a range of spatial scales suggests that abalone distribution patterns are fractal (Sugihara and May 1990).

At the scale of 0- to 10-m, populations of abalone actively aggregate around fixed positions which are favourable for feeding or breeding (Shepherd 1986; Prince 1989*a*). At a scale of 100's to 1000's of metres, these aggregations are clumped within reef complexes to form metapopulations (Shepherd and Brown 1993) that abalone divers call "abalone beds." In turn metapopulations or abalone beds will be common along sections of coastline 50- to 100-km long where rocky substrate and algal growth support them, but nonexistent or limited on adjacent sections of coastline lacking these features.

Visually searching divers learn the locations of the abalone beds and the small component aggregations within them (Prince 1989*a*). In a developed abalone fishery, divers spend little time randomly searching for abalone. Divers check the condition of known abalone beds by looking at the state of its best aggregations before deciding whether or not to dive in that location. One consequence of this is that catches tend to remain proportional to time spent diving, rendering catch rate a poor indicator of stock abundance (Prince 1989*a*).

Restricted movement and dispersal

Larval and adult movements are generally limited to scales of 10's to 100's of metres (Prince et al. 1987, 1988; McShane et al. 1988; Brown 1991; Shepherd and Brown 1993). Some level of interaction is probable between the aggregations within a metapopulation (Shepherd and Brown 1993) but the interaction through adult movement and larval drift may be low or unidirectional. It is unlikely that interactions occur between metapopulations on different reef complexes. Consequently abalone fisheries are made up of many 100's to 1000's

Fig. 4(*a*). A map of George III Rock in southeast Tasmania showing the 29 blocks of equal size for which Leslie estimates of the abalone populations size were derived (from Prince 1989*a*).

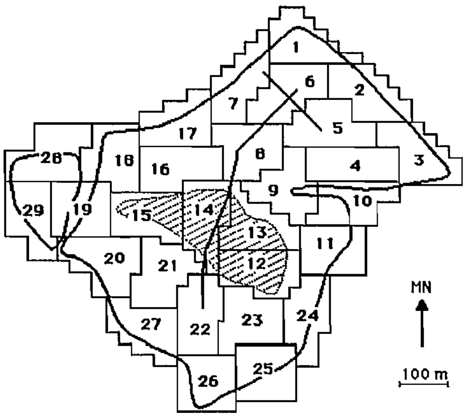
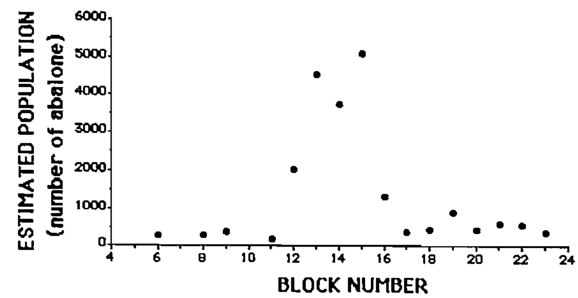


Fig. 4(*b*). Leslie estimates of abalone population size in 29 blocks of equal area across George III Rock in southeast Tasmania (from Prince 1989*a*).



of discrete functional units of stock (Gulland 1969). Serial localized depletions of abalone beds occurring over an extended time frame can apparently lead to the decline of large abalone fisheries as may have occurred in Mexico (Prince and Guzmán del Próo 1993).

Variable patterns of growth and fecundity

Patterns of growth and fecundity vary greatly between and within metapopulations (Shepherd and Laws 1974; Prince 1989*a*; McShane 1991). Maturity is determined principally by age, rather than size (Nash 1992). Abalone of the same species commence breeding at around the same age over broad regions but their size at maturity varies greatly. At maturity cryptic juvenile abalone emerge from under boulders and take up exposed positions and become vulnerable to fishing (Prince 1989*a*). In productive fast growing areas, abalone mature and emerge at larger sizes than in slower growing areas. When legal minimum sizes are applied across an abalone fishery, the breeding stock in slow-growing areas is given a higher level of protection than in fast-growing productive areas (McShane 1991). Moreover fishing pressure tends to concentrate on the faster-growing areas because that is often where legal-sized abalone are most easily found. While protecting breeding stock in many areas a high minimum size limit leads to local depletions in the fastest growing and most productive areas of the fishery (Sluczanowski 1984; Hilborn and Walters 1987).

The uncertain status of Australia's abalone fisheries

Because state fisheries authorities in Australia do not allocate sufficient resources to the monitoring of abalone populations the current status of the Australian abalone fisheries cannot be determined with any quantitative rigour (Prince 1989*a*; Prince and Shepherd 1992). Rather, Australian managers rely qualitatively on regional trends in catch and catch rates to annually set TACCs of abalone (e.g., Keesing and Baker 1998). The stability of TACCs in most states and the fact that quotas are filled each year is used to argue that the introduction of ITQs and the subsequent industry initiated catch reductions of the mid-1980's have stabilized stocks in most states. However, definable threats to the long-term sustainability of the resource exist and their impact remains unmonitored.

The normal legal fishing pattern of licensed commercial harvesters can lead to the serial depletion of individual reefs even if TACCs are set at conservative levels for the fishery. This is because many divers may catch their individual quota allocations from the same abalone bed giving rise to a "tragedy of the commons" situation. Fishing pressure naturally concentrates in certain areas, e.g., abalone beds close to access points and home ports where the costs of fishing are lowest and on shallower reefs where decompression requirements are lowest or where a decompressing diver can kill time by searching for abalone (Prince 1989*a*). Divers also favour diving on fast-growing populations where legal-size abalone are most easily found. Size limits and quotas set over broad zones of the fishery give little protection to these favoured dive areas where fishing pressure focuses.

Illegal fishing pressure also raises concerns over sustainability. In New South Wales, it is estimated that the abalone catch by illegal commercial divers is at least equivalent to that of the legitimate commercial industry and may be double the commercial catch (Prince 1989*b*). The impact of illegal exploitation is particularly damaging to the long-term sustainability of the resource because the amount taken is uncontrolled and legal size limits are usually disregarded. As accessibility to coastal areas increases, amateur fleets grow in size, and diving equipment and modern navigational electronics become increasingly available, it is expected that the illegal catching of abalone for sale will pose an increasing threat to the sustainability of the abalone resources (Prince and Shepherd 1992).

Declining water quality in inshore environments is also an increasing threat to the fishery. Burgeoning coastal development and agricultural inputs increase inshore nutrient loadings and destabilize salinities. This combination of conditions has apparently caused mass mortalities and disease problems off the coast of suburban New South Wales and the mouth of the Blackwood River, Western Australia (D. Leadbetter, Ocean Watch, New South Wales, Australia and T. Adams, Western Australian Fishing Industry Council, Western Australia, Australia, personal communications).

All these impacts can lead to the ongoing loss of abalone populations and an erosion of the abalone resource. In the short term this leads to a loss of potential production. In the long term, if the continuing loss of abalone populations reduces the productive areas beyond the point where current TACCs can be sustained, the fishery will destabilize (Prince and Shepherd 1992). But with no effective system of quantitative stock assessment in place there is no way these processes can be monitored or their aggregate impact assessed.

Reef-by-reef management

The knowledge and techniques required for the optimal, sustainable management of the Australian abalone resource have been developed and are known. Each abalone bed requires its own specifically tailored management plan with total allowable catch, size limits, and monitoring regime (Prince 1989*a*; Shepherd and Brown 1993). However, in Australia there is not a single population of abalone which can be quantitatively shown to be being harvested sustainably. The government agencies charged with this responsibility are incapable of collecting sufficient high quality data or effecting management plans at a small enough scale. The conundrum they face is this: how does a modern, centralized, small government manage this valuable but spatially intricate resource when fiscal reality prevents monitoring, management, and enforcement at an appropriately fine scale? Despite the aggregate value of the resource no centralized, economically rational, small government can monitor, quantitatively assess, or manage the resource optimally. A democratic, liberal society with centralized priority setting will always favour spending scarce tax revenue on hospitals, welfare, and government works, over spending on monitoring and policing the harvest of abalone. The public sector fisheries biologist charged with assessing and managing spatially complex abalone populations with minimal resources faces an impossible task.

As it is currently structured, reef-by-reef management is an impossible dream in the Australian abalone fishery. The tragedy of the commons and a tyranny of scale forces our society to manage this resource suboptimally. The existing management framework is structurally unable to meet the challenge of assessing and managing this spatially intricate renewable resource.

Optimizing Australian abalone management

Hardin (1968) argued that the "tragedy of the commons" does not have a technical solution; rather it is a social issue requiring society to change and voluntarily relinquish existing rights and freedoms.

The Zone 2 abalone divers of south Western Australia (Fig. 2*a*) voluntarily practice "concept fishing" in an attempt to maintain and build production from a depleted high growth area previously overfished using legislated minimum size limits and TACCs (T. Adams, Western Australian Fishing Industry Council, Western Australia, Australia, personal communications). When fishing in the "concept area" (Fig. 2*b*) the Zone 2 divers voluntarily: (*i*) co-ordinate their diving effort to ensure each aggregation of abalone is only harvested once a year and share their daily catches; (*ii*) refrain from harvesting an aggregation of abalone if they see that it has not rebuilt since the previous year; (*iii*) use a self-determined minimum size limit above the legal minimum size limit. The divers only harvest abalone that have finished their rapid growth phase (in terms of both shell length and volume). They judge this by the depth and roundness of abalone shells; and (*iv*) remove no more than 30% of the abalone in an aggregation above their self-determined size limit, selecting the abalone from across the size range available rather than just taking the biggest.

Growing catches and positive reports on stock levels suggest that the Augusta concept plan is rebuilding the abalone beds in their concept area. However, with no legal underpinning the voluntary co-operation needed to foster this experiment in fisheries management easily and often breaks down. There is no guarantee that long-term personal benefit will accrue from the short-term cost of this conscientious stock management. Years of co-operating can be negated by a short period of unco-operative but legal behaviour. The existing legal framework is a blunt instrument in which behavior is often determined by the lowest common denominator and the creed: "if I don't do it, somebody else will."

It has been argued that transferring greater responsibility for management to users of renewable resources fosters economically efficient and sustainable harvesting of renewable resources (Kesteven 1988; Keen 1991; Young 1992). We argue that for abalone stocks and other species with geographically restricted populations this responsibility for management must be linked to defined areas and populations. A form of territorial users rights is necessary in this fishery (TURF) to enable individuals, or small groups of individuals, to manage at a scale appropriate for the functional units of stock.

A TURF system would give abalone divers (or small groups of divers) secure harvesting rights to specific abalone beds and exclude others from harvesting abalone in those areas. Divers could then be expected to look after their own long-term interests by developing the skills needed to manage their own abalone beds. Most experienced abalone divers have observed population trends on the abalone beds they fish regularly and have well-developed ideas on how abalone should be managed. The principles of the Augusta concept plan show how sophisticated these home-grown ideas can be. However, under current arrangements, these ideas are seldom implemented because of the "tragedy of the commons" dilemma. Most abalone divers would willingly tend valuable abalone beds like gardeners tending their gardens if our system of social constraint encouraged rather than discouraged this behavior.

Easily managed nuggets

It is economically feasible to manage abalone populations intensively. Abalone stocks are concentrated into valuable nuggets of stock; a square kilometre of productive reef area such as George III Rock (Figs. 4*a* and 4*b*) may sustainably produce an annual 2–4 t of abalone with a gross value of A$50–150 000 (Prince 1989*a*). Intensive management would involve few costs over and above the existing ones. Most of the infrastructure required is already used by the existing catching sector of the fishery and, if forthcoming, the voluntary behavior of harvesting divers is free. The major cost would be for ongoing population monitoring and quantitative stock assessment if these were required. However, once permanently established with existing techniques, monitoring and stock assessment on an area this size need take no more than 4–6 personnel weeks per annum, worth approximately A$5–10 000. While far beyond the level of resources a centralized agency would devote to a single reef, a private operator could afford this cost over and above minimal costs of normal harvesting.

Under TURF management abalone harvesters would become directly responsible for planning both their harvesting and stock management strategies for defined abalone beds. This would eventually include catch levels and the size of capture. They would also assume responsibility for monitoring and securing their own abalone beds. The government role would shrink to supporting the development of optimal management skills among abalone harvesters and to verifying, on behalf of the community, that predetermined minimum standards of operation are observed.

Under this regime the value of an entitlement to harvest abalone would become linked to the expected production from a defined abalone bed. Economic imperatives would favour the harvester who can optimize long-term harvest rates by optimizing management (Kesteven 1988; Keen 1991; Young 1992). New information and changes in the condition of resources are more efficiently assimilated by individuals than by centralized governments; therefore, we should expect management to become innovative, experimental, and adaptive. Multiple experiences with many different units of stock will present great opportunities to learn through adaptive management (Walters 1986; Walters and Holling 1990).

The issue of incremental resource degradation from diffuse external threats (i.e., pollution and illegal harvesting) is also more likely to be confronted under TURF management. Abalone harvesters would be committed to ensuring long-term productivity from specific areas of reef. At the present time abalone divers give way when a stock declines due to environmental damage, recreational, or illegal fishing pressure. Rather than addressing the threat, harvesters relocate their operation placing greater pressure on the dwindling number of remaining productive beds. Under TURF management harvesters would not be able to relocate without purchasing the rights to new abalone beds. This will create an incentive for harvesters to address problems of eutrophication, siltation, habitat destruction, or illegal use in their areas. With strong financial commitment to the integrity of the natural environment in specific locations, abalone harvesters can be expected to evolve into environmental watchdogs guarding the integrity of the inshore marine environment on behalf of the rest of the community.

Precedence

Territorial user rights fisheries have considerable precedence. In Europe and North America some stocks of intertidal bivalves are managed as private property where it has been found to maximize production and minimize surveillance by managing agencies (Beattie et al. 1982; Bourne 1986).

Japanese prefectures continue to manage their own fisheries on a basis of local corporate ownership of an area of fishing ground (Mottet 1980; H. Kojima, Tokushima Prefectural Fisheries Experimental Station, Hiwasa-cho, Kaifu-gun, Tokushima-ken 779-23, Japan, personal communication). Despite the ongoing slow decline of Japanese abalone catches in recent times, the stability of Japanese catches over hundreds of years of exploitation argues that the Japanese have had considerable success in managing their abalone stocks sustainably.

Most marine resources were managed as territorial rights by the traditional societies of Oceania, the reef tenure providing the motivation for conservation (Ruddle and Johannes 1983). The displacement of traditional TURF-type management and the introduction of a law-of-the-commons framework is now encouraging the use of destructive fishing practices involving poisons and explosives. The power of villages, clans, and chiefs to control their own fishing reefs has been eroded while the governmental authorities which nominally take control, lack sufficient resources to monitor, manage, or enforce (Johannes 1992; De Allessi 1997).

In stark contrast to the general trend in Oceania, a recent innovation in Vanuatu has seen the strengthening of village control over the management of local stocks of the marine gastropod *Trochus niloticus* (R.E. Johannes, 8 Tyndall Court, Bonnet Hill, Tasmania, Australia 7053, personal communication). The results have been spectacular. With the support of some basic biological education, traditional village-based power structures have reasserted control over reef areas determining when they can be fished. Introduced on a trial basis in a few villages, the success of the initiative can be gauged by its rapid spread to other villages and the way the villagers have extended the concept to other species. Similarly a form of TURF management has recently been implemented in the Chilean fishery for the gastropod *Concholepas concholepas* with considerable success (Castilla et al. 1998). As in Vanuatu, early indications in Chile are that small, relatively nontechnical, local communities controlling their own reef areas are capable of sophisticated and creative management decisions.

The apparent effectiveness of TURF in traditional societies with low levels of scientific training and few governmental resources suggests that TURF could also be successful in technologically advanced countries such as Australia.

Challenges to the implementation of TURF for Australian abalone

Collectively we authors have spent considerable time discussing TURF management with a wide cross section of abalone resource stakeholders in Australia. We have spoken publicly at conferences, workshops, and annual meetings of associations and discussed it informally in numerous private conversations. There is widespread support for subdividing the Australian abalone fisheries into smaller zones (100's of km) each with fewer divers in order to reduce competition between divers and encourage divers to "farm manage" the resource (Prince and Shepherd 1992). However, support for TURF management is more mixed. In each fishery there are strong pockets of support for changing to a TURF arrangement but an ill-defined resistance to change is more pervasive.

Concern is expressed about the exclusive nature of the harvesting rights underpinning TURF management. In this context it needs to be noted that territorial user rights need not exclude other compatible uses for TURF areas; they would simply create exclusive harvesting rights for abalone in specific areas. It should also be noted that exclusivity is already a feature of the existing fisheries. Limited entry and ITQ systems are exclusive; a limited amount of commercial divers are allowed to gather abalone for sale. In addition most abalone fisheries already have areas reserved for recreational, indigenous, or preservationist groups and commercial abalone divers are excluded from these areas. This zonation of the existing fisheries provides a starting point from which the broader community can ensure, through political processes, that all stakeholder groups maintain equitable access to the resource.

A change to TURF management would further reduce the existing right of stakeholders to move relatively freely around their fisheries. All stakeholders would be excluded from many of the areas in which they currently operate and restricted to operating in some smaller subset of those areas. Hardin (1968) argues that the tragedy of the commons does not have a technical solution; rather it is a social issue requiring members of a community to voluntarily relinquish existing rights and freedoms.

As might be expected, the willingness of the existing stakeholders to voluntarily relinquish existing rights of free movement seems to relate to how strongly they perceive their own need for change. Most abalone divers we have spoken with acknowledge the long-term gains that would be made by optimizing the management of abalone beds with TURF. However, those from fisheries with good stocks of abalone generally value their freedom of movement and relative lack of responsibility too much to support changing. It is the divers from areas with perceived stock problems and a strong interest in rebuilding stock levels that tend to be most supportive of a change to TURF management. For this latter group, existing rights of free movement are devalued by their concern for the long-term viability of their stocks.

Allocation

The impossibility of converting the existing ITQ allocations into an equitable allocation of areas is another factor commonly cited in conversations as a barrier to changing the existing management arrangements. However one possible strategy for equitably converting allocations has already been devised by Dan and Danielle Pollock of the West Coast Abalone Harvesters of British Columbia.

The method they proposed involves the following steps. (*i*) Grid the available coastline using an appropriately fine scale (1 km^2). (*ii*) Each stakeholder then assigns their own value to each grid square using a scale of 0–10, zero indicating no value and ten indicating maximum value. Individuals define their own personal reasons for assigning value, including stock abundance, fishing history, accessibility, and suitability for diving. (*iii*) The total perceived value of each square is then determined by summing the values assigned to each square by the stakeholders. (*iv*) The total perceived value of the fishery is then determined by summing the perceived value of all the individual 1-km squares. This total perceived value of the fishery can then be compared to the existing TACC and a conversion rate calculated between ITQ units and units of perceived value. (*v*) By consensus the grided 1-km^2 squares may then be amalgamated to form a smaller number of larger areas with approximately equivalent perceived value. These larger units of approximately equal perceived value could be called TURF units. (*vi*) A ballot is then used to allocate TURF units in proportion to the ITQ holdings of each stakeholder. (*vii*) Once this balloted allocation is completed stakeholders can begin trading TURF units in order to rearrange TURF holdings in line with their individual requirements.

There are undoubtedly other ways of allocating areas so that a TURF management strategy can be implemented. However, the system outlined above meets the necessary criteria of being equitable, open, and above manipulation by individuals or groups (Hively 1995).

Concluding comments

Using the specifics of the Australian experience with the research and management of abalone stocks together with our wider fisheries experience, we have argued that the spatial scale of an exploited stock should be an important determinant of management strategies. Where the spatial scale of the functional units of stock within a fishery is smaller than the effective scale of management, a tragedy of the commons situation may arise despite otherwise sophisticated management. Component stocks within the fishery can be overexploited and a serial depletion of stocks may occur. From our experience fished stocks with localized patterns of movement and dispersion, including many tropical reef and invertebrate species, are particularly prone to these localized impacts. We suggest that management through territorial user rights would allow individual or small communities of fishers to adaptively adjust the scale of management to the scale of the stock. There may be other strategies for achieving this same end but our theory is that current trends in modern government mitigate against the current system of zonal size limits, effort limitation, and ITQs optimally managing spatially intricate renewable resources.

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