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1. INTRODUCTION

Failure to manage the impacts of commercial and recreational fishing at spatial scales that match the biological scale over which marine populations function may have undesirable long-term consequences for fisheries resources (Ludwig et al. 1993; Carvalho and Hauser 1994; Botsford et al. 1997; Orensanz and Jamieson 1998; Hilborn et al. 2003a/b). Conservation of spatial population structure is especially important where organisms exhibit diverse life-history characteristics such as growth and mortality, maturation, and dispersal rates over space (i.e., biocomplexity: emergent properties of components of a system working together in a complex manner). Biocomplexity buffers an ecosystem to change due to nonlinearity in ecosystem dynamics (Levin 1998), and biocomplexity in the form of spatial population structure is important for maintaining the resilience of populations in highly variable environments (Holling and Meffe 1996; Hilborn et al. 2003b; Berkeley et al. 2004).

Most conventional fisheries stock assessment and management approaches assume that fisheries harvest single, panmictic (i.e., unstructured in terms of mating populations) stocks that exhibit stationary average life-history characteristics (Gulland 1969). For some fisheries, harvest information is detailed enough and fish population structure is coarse enough (e.g., via migration and dispersal) to account for whatever stock structure appears to exist. For instance, although stock structure exists for Pacific Ocean perch (*Sebastes alutus*) (Gharrett et al. 2006), their relatively high movement and mixing has allowed most fisheries to continue without fully depleting the stock. Notwithstanding the success of some Pacific Ocean perch fisheries, most assessment and management systems do not collect information at the small scales necessary to account for the spatial heterogeneity of harvested marine organisms (Ludwig et al. 1993; Carvalho and Hauser 1994; Botsford et al. 1997; Orensanz and Jamieson 1998; Prince 2005). For

Yamanaka and Lacko 2001). Effective management of sedentary species often depends on an adequate match between the spatial scale of management and the spatial scale of sedentary populations (Prince 2005). Prince (2005) defined the spatial scale of sedentary stocks, or the actual scale of component units of stock, as self-recruiting units of stock, where population exchange between units of stock occurs at a low rate.

A ótragedy of the commonsô (Hardin 1968), where overexploitation results from individuals maximizing their own welfare, may result from unsustainable fishing pressure on fish populations when resource access is not regulated (Hilborn et al. 2005). Effects of the tragedy of the commons are of particular concern for species with slow body growth, longevity, late age of sexual maturity, low rates of population increase, and relatively large body size. These species are referred to as óK-selectedô species (MacArthur and Wilson 1967) and they have low sustainable yields in relation to virgin biomass (Hilborn 2003a). Rebuilding populations of K-selected species following overfishing therefore occurs at a relatively low rate.

A tyranny of scale is the mismatch between the scale of management and the scale of component units of stock (Prince 2005). A tragedy of the commons may increase a tyranny of scale because fishers have little incentive to cease fishing pressure on a sedentary population (Prince 2005) because continual fishing on a single sedentary population requires lower effort and is more cost-effective than searching for new fishing grounds.

S

1.1. KS^n fisheries

Parma et al. (2001) referred to small-scale fisheries for spatially-structured, sedentary stocks as óS-Fisheriesô because this particular category of fishery can be described by several óSô words. Specifically, Parma et al. (2001) identified fisheries that: (i) are ósmall-scaleô in terms of the size of fishing vessels (small boats normaS

depletion. There has been limited attention paid to fisheries for species that are also susceptible to both a tyranny of scale and serial depletion.

1.2. Biology of KS^n species

Regarding life-history, r-selection and K-selection relate to the selection of organism traits that permit success in particular environments (MacArthur and Wilson 1967). The intrinsic rate of population increase, órô, is the sum of the change in the amount of harvestable stock estimated by recruitment and growth minus natural mortality. órô is used as a measure of how much a population can increase over time. Species with high órô values, or ór-selectedô species, typically have the ability to recover population size relatively quickly because the stock productivity (e.g.,

Most species of rockfishes are K-selected because they are long-lived (20-140 years; Archibald et al. 1981; Leaman and Beamish 1984; Love et al. 1990), relatively unproductive (Adams 1980; Musick 1999), and reach sexual maturity at relatively old ages, ranging from 11 to 20 years depending on species (Yamanaka and Richards 1993; Kronlund and Yamanaka 2001). Furthermore, rockfish have a relatively large body size, and although some species produce up to 417,000 eggs per female (boccaccio ï *S. paucispinis*; Haldorson and Love 1991), they tend to have low larval survivorship (Musick 1999). Some r

2005, for abalone). Localized depletion is documented in several fisheries. For instance, localized depletion of global sea urchin (*Strongylocentrous spp.*) resources has occurred at a range of scales, as has the over-fishing of the larger, older individuals (Botsford et al. 2004). The principal cause of sea urchin serial depletion and age-structure truncation has been the movement of fishers to select areas of high sea urchin density to maximise profit (Botsford et al. 2004). A management regime was not in place to detect and halt the localized depletion. Localized depletion due to fishing pressure in marine finfish was reported in Hanselman et al. (2007) for north Pacific rockfish. Again, a tyranny of scale is thought to be the mechanism that drove the localized depletion.

The effect of localized depletion is likely more severe in KS^n fisheries than in fisheries for species that are not K-selected. For instance, it may take decades for some species of rockfish to re-colonize and rebuild their population age-structure, due in part to the low productivity of

1.3.1. Fishery management

One of the main roles of fishery management is to specify the total allowable catch (TAC) that may be taken from a management area or stock if the

challenging not only due to hyperstability in CPUE data. There is also generally a deficiency of life-history data for long-lived species (Love 2002), and the susceptibility of some KS^n species to barotrauma complicates the use of in-situ stock monitoring (i.e., direct observation) since tagging techniques that require the fish be brought to the surface cannot be used. The expense of monitoring isolated populations and the difficulty in delineating stock boundaries further complicates assessment of KS^n fisheries. Also, KS^n fisheries target species with highly-variable recruitment success thereby complicating methods of stock assessment which are unable to

For this study, a selection of KS^n fisheries were chosen as candidate ómodel fisheriesô. Through a review and synthesis of specific elements of the candidate models, particular model components were assessed regarding their effect on the sustainability of each fishery.

2.3.1. Sustainability criteria

Hilborn et al. (2003a, 2005) hypothesize that fisheries management success depends on three criteria:

(i) the spatial scale of management must match the spatial scale of the biology and population dynamics of the resource;

(ii) the resource access and allocation methods must create incentives for and sustainability; and

(iii) the decision-making structure of the institu 1 379.996vn28.87 53Tm4C B671 0 0 1 178.46 53

The criteria described by de la Mare (1998) require more biological information than the first three criteria, and are based more upon computer simulation than resource access and decision-making structure. However, developing measurable management objectives (the fourth criterion) inherently requires involvement by decision-makers. For instance, fishery stakeholders are required to work together to form management objectives which are necessary for the fourth criterion.

In general, Hilborn et al. (2003a, 2005) focuses upon relatively broad social and

connectivity through larval propagule dispersion is a conservation concern in KS^n fisheries because reproductive adults are generally sedentary (Buonaccorsi et al. 2005). Therefore, the dispersion of larval propagules was examined in each model fishery to determine if the spatial scale of management was sufficient.

Criterion 2: Resource access and allocation

Fisher incentive for resource sustainability requires two crucial elements. First, fishers must be provided with harvesting or territorial rights to fish, with particular emphasis on long-term and secure rights (Hannesson 2004). Second, access rights must be enforced to protect the value of the assets and encourage a sustainable flow of benefits from a fishery (Grafton et al. 2006). A tragedy of the commons may be avoided if fishers are granted a level of ownership or exclusive access to a resource because fishers may be motivated to pursue sustainable management of the resource (e.g., Hilborn et al. 2003a, 2005; Maguire 2003; Grafton et al. 2006).

Fishing rights may take several forms based on the level of resource exclusion and the size or composition of the bodies holding the rights (Grafton et al. 2006). Access rights range from open access

Australia, has substantial recreational and commercial fishing sectors, and both user-groups are regulated with a TAC (Jackson et al. 2005). In comparison, the sea urchin fishery in British Columbia, Canada, is harvested almost exclusively by the

often cause ineffective fishery management and may result in overfishing (Healey and Hennessey 1998).

Criterion 4: Measurable management objectives

The importance of both clearly stated fishery management objectives (e.g., Shepard 1991; World Bank et al. 1992; Pido 1995; Berkes et al. 2001) and *measurable* fishery management objectives have been emphasized in the literature (e.g., Barber and Taylor 1990; Francis and Shotton 1996; Murawski 2000; Sainsbury 2000). When fishers have common objectives they become an accountable partner and are actively involved in decision-making regarding allowable harvest levels and allocation of fish among users. Also, fishers gain a sufficient understanding of how fishery management decisions are made, and make difficult decisions regarding fishery management (Christy 1982; Lane and Stephenson 2000; Berkes et al. 2001; Hilborn et al. 2003a, 2005; Grafton et al. 2006).

Management objectives operationally support management goals and as such should be measurable and verifiable statements (Barber and Taylor 1990). There are typically two groupings of fishery management objectives. The first are

The clarity and measurability of management objectives were reviewed for each fishery to gauge the presence of measurable management objectives. Clarity of management objectives was assessed based on how the management objectives were determined and whether the management objectives were specific to each managed stock. Measurability of management objectives was assessed based on whether the objectives were aspirational or measurable.

Criterion 5: Management procedure based on decision rules

According to de la Mare (1998), fisheries management policy requires the advance specification of all management actions that should be taken in all circumstances. A management procedure avoids potential gaps in policy by specifying a feedback control system consisting of a set of decision rules to set, remove, or vary management regulations in response to changes in stock status (Butterworth et al. 1997; Cochrane et al. 1998; de la Mare 1998; Butterworth and Punt 1999; McAllister et al. 1999). Management procedures further specify what data will be collected, how the data will be collected and processed, what estimates will be made from the data, and how the estimates will determine harvest controls (Bentley et al. 2005). Also, a management procedure involves weighting multiple management criteria and requires the specification of measurable management objectives (de la Mare 1998).

Harvest control rules are often used in fisheries management to specify catch quotas or fishing intensity in terms of some other variable regarding the status of a stock, such an index of spawning biomass (Restrepo and Powers 1999). Such rules are typically designed to be precautionary (Rosenberg et al. 1994) and thus represent an essential component of a management procedure (de la Mare 1998). Stock threshold levels, or reference points, include lower limit reference points (LRPs) to set ñboundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yieldò and target reference points which ñare intended to meet long-term management objectivesò (UN 1995). As such, a LRP may be considered a form of decision rule to dictate management action based on an

index of stock size or health. The specification of measurable and operationally-unambiguous definitions of LRPs is used as a precautionary measure in fishery management to avoid overfishing (Rosenberg et al. 1994; Caddy 2004) and to meet specific fishery goals (Hilden 1993; Leaman 1993; Rivard and Maguire 1993).

Criterion 6: Assessment based on specific data and methods

In a MOP, assessments require the collection of specific data and parameter estimates by agreed-upon methods (de la Mare 1998). An assessment is a scientific judgement to advise a

(McAllister et al. 1999). A prospective evaluation is similar to a management strategy evaluation (Hilborn 1979), a decision analysis framework, or a harvest strategy evaluation. A prospective evaluation includes both a prospective component and performance measures, derived from measurable management objectives, to present outcomes and demonstrate the likelihood that the management system will meet its objectives (de la Mare 1998).

Specific measures of sustainability/success, both biological and economic, are difficult to determine for a fishery (Hilborn 2003b). Determining the biological and economic sustainability of KS^n fisheries is particularly challenging due to a paucity of data and often unreliable, or non-

fisheries lacked any form of reference point. Reference points are related to decision rules and as such are covered in detail under Criterion 5, below.

Finally, Table 3 lists the quota allocation scheme/access structure of the dominant user-group of each fishery, covered in detail under Criterion 2, below. Five fisheries employed limited

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(St. John et al. 2004). The co-management process for the VRL fishery, which was not formalized until 2003, was developed through consultation with license holders, fishery managers, and fishery officers (Anon 2003).

Criterion 4: Measurable management objectives

The majority of sustainable fisheries met criterion four (Table 6). The SBPS, NZRL, and WARL fisheries had clear and quantifiable management objectives and were relatively sustainable (Table 5). The VRL, BCGD, VAB, and CL fisheries had clearly stated and measurable means with which to work toward non-measurable management objectives, and were also relatively sustainable.

The management objective of the WARL fishery was that ñmanagement arrangements adopted would ensure that the abundance of breeding lobsters is maintained at or above the levels in the late 1970s/early 1980s (i.e., about 20-25 per cent of the unfished parental biomass)ò (RLIAC 1999). The estimated 1980 level of biomass (approx. 22% of unfished parental biomass) was assumed sustainable and was therefore chosen as a lower limit that breeding stocks are to remain above under future management (de Lestang and Melville-Smith 2004). The management objective was not specific to any of the three stocks in the fishery and, similar to the SBPS fishery, the management objective did not specify a timeframe for rebuilding. At present, all three stocks were close to maximum sustainable yield and breeding stock was at or above target levels in each of the three management areas (de Lestang and Melville-Smith 2004).

A total of six management objectives were employed in the NZRL fishery. These management objectives were used to develop candidate harvest control rules for each of ten

Jackson et al. (2005) conducted a study of some of the most popular recreational marine fisheries in Australia and found that óclear and quantifiableô management objectives were only present in the SBPS fishery.

The VRL, BCGD, VAB, and CL fisheries lacked measurable management objectives, but employed relatively clearly stated and measurable means with which to work toward management objectives. For this reason, the clarity and measurability of the means to work toward the management objectives were assessed in these fisheries. For example, one of the management objectives the VRL fishery was the ósustainability of the rock lobster resourceô (Anon 2003). To reach this goal, strategies such as the implementation of a lower reference point based on spawning level were employed.

The remaining fisheries employed clearly stated, yet non-measurable objectives. For example, in the BCSU fishery, the ócollection of biological informationô is listed as one of the primary management objectives, to better understand growth and recruitment parameters of the resource (DFO 2006c). The only exception was the WAD fishery, for which no management objectives were stated.

Criterion 5: Management procedure based on decision rules

The majority of sustainable fisheries met criterion five (Table 6). Fisheries that incorporated a specific management procedure based on decision rules were relatively sustainable, although all fisheries incorporated some form of decision rule (Table 5). Fisheries with relatively dynamic decision rules, where the TAC was updated annually for egmef1801 0 0 1 212.ucas updat

that quantified the probability of rebuilding biomass to a pre-specified level, or to mandate an assessment of the stock based on CPUE data. Decision rules were applied within the context of a management procedure and were tested within a simulated feedback system (Starr et al. 1997; Bentley et al. 2003; Breen et al. 2003). In the NZRL fishery, measurable performance indicators were associated with each of six management objectives. For instance, both mean and median annual catch and the probability of falling below the current TAC were used as performance indicators to achieve the management objective of maximizing catch.

Reference points used in each fishery are summarized in Table 3. Onl(((t)-4(altBT1 0 0 1 413.23 559.6)

allowed for annual variation in TAC, the actual TAC has been constant since quotas were first introduced in 1988. At present, the fishery is assessed as stable and fully-fished, and is therefore considered relatively sustainable because it is not overfished (DNR 2002).

Criterion 6: Assessment based on specific data and methods

Fisheries which conducted annual assessments were relatively sustainable, although conducting annual assessments was not a requirement for fishery sustainability (Tables 2 and 5). For example, the BCSU fishery conducted assessments every two years and was relatively sustainable. Fisheries that conducted assessments at irregular intervals or that did not conduct assessments were for the most part unsustainable. Fisheries with relatively complex stock assessments were sustainable. The CL fishery was the only fishery which required individual fishers to hire consultants to assess their fishing grounds, a measure which seems to work quite well. The majority of sustainable fisheries met criterion six (Table 6).

With the exception of the GMGG and CBC, all fisheries conducted periodic stock assessments. The SBPS, DSR, NZRL, WARL, VRL, BCGD, VAB, and CL fisheries conducted annual assessments, while the WAD and IR fisheries conducted assessment at irregular intervals. The BCSU fishery conducted assessments every two years. There were no assessments of the GMGG fishery before closure in 1990 (SEDAR 2004), and the first assessment of CBC was conducted one year before ónoretentionô management was initiated (Butler et al. 1999).

Methods used to conduct assessments varied among model fisheries. For example, the NZRL fishery conducted relatively complex and data-intensive Bayesian length-based stock assessments to simultaneously estimate recruitment, mortality, growth, maturity, selectivity, and seasonal vulnerability parameters (Starr et al. 2003; Bentley et al. 2005). To address the spatial structure of the managed stvir asrt Bmhe WCSU for an[(st)0(v)11(i)-4(t)-4(y)11(, and)]TJ23]TJT1 0 at tsme3 224.2

The daily egg production method was used for annual assessment of the size of snapper spawning biomass in the SBPS fishery, and due to large variances around estimates of egg production, DEPM estimates of snapper spawning biomass have often been imprecise (Jackson et al. 2005). Age-structured models were used in 2003 to refine

Criterion 7: A prospective evaluation of the management procedure using performance measures

The NZRL fishery was relatively sustainable and was the only fishery that employed a prospective evaluation of a management procedure using performance measures, employing extensive simulation trials testing various management procedures, harvest control rules, and performance measures to identify procedures that would rebuild biomass to a target level in a specified period of time; an approach which has proven successful (Bentley et al. 2005).

However, six other sustainable fisheries employed a form of prospective evaluation of their management strategy in the absence of a prospective evaluation of a management procedure using performance measures, as specified by de la Mare (1998). The majority of the remaining fisheries, which did not employ any form of prospective evaluation of their management strategy, were considered less sustainable (Table 6).

In the absence of a management procedure, the presence of a prospective evaluation, to either assess management strategies or to revise stock parameters, was reviewed for each fishery. Along with the NZRL fishery, the SBPS, WARL, VRL, BCGD, VAB, and CL fisheries employed a prospective evaluation of their management strategies. In the SBPS fishery, age-structured models were used to explore likely trajectories of mature biomass for a range of future catches (Jackson et al. 2005). In the WARL fishery, prospective modeling was used to assess stock sustainability and to forecast future catch levels (de Lestang and Melville-Smith 2004). In the BCGD fishery, age-structured projection modeling was used to assess the impact of various harvest rates on the fishery (Zhang and Hand 2006). In the VRL fishery, a prospective evaluation was used to examine the impact of alternate harvest strategies and various stock parameters on both spawning and available biomass (Anon 2003). In the CL fishery, models regarding fisher decision-making have recently been employed to determine harvesting decisions, and changes in TAC are assessed annually (Gelcich et al. 2007). The remaining six model fisheries (WAD, DSR,

GMGG, CBC, IR, and BCSU) did not employ any form of prospective evaluation of their management strategy.

2.5. Discussion

The goal of this study was to identify a fishery management system that may potentially provide a sustainable IR fishery in British Columbia, despite the major challenges and ris

(vi) low fishing intensity.

This would explain why seven relatively sustainable fisheries did not meet the first criterion (Table 6).

The presence of catch quotas for each major user-group was related to sustainability in KS^n fisheries, and fisheries with higher levels of resource exclusion were more sustainable (Table 6). Assigning catch quotas to each user-group is a form of exclusive access which provides motivation for sustainable resource use (Hilborn et al. 2003a, 2005; Maguire 2003; Grafton et al. 2006) and works to decrease a tragedy of the commons (Hardin 1968; Hilborn et al. 2005). The NZRL fishery was the only sustainable fishery that did not have a designated quota for all fishing sectors; sustainability in the NZRL fishery results from the presence of other criteria, discussed below.

Fisheries with devolved and less complex decision-making structures were relatively sustainable

sustainable. The only fishery without any documented management objective was the WAD fishery, which was considered relatively unsustainable.

Due to a general paucity of data in all other model fisheries, only the NZRL fishery employed a management procedure based on decision rules as specified in a MOP (de la Mare, 1998). However, all fisheries incorporated some form of decision rule (a crucial element of a MOP)

successive criteria are inherently dependant upon some prior criteria. This is evident in the methods section above, as several surrogate measures were developed to address this challenge.

The DSR fishery was unlike the other fisheries in several ways because it incorporated the seven criteria to a relatively low extent, yet was considered relatively sustainable. This is most likely because of the unique access structure of the DSR fishery. Specifically, the commercial DSR fishery only occurs following the full accounting of all DSR catch in all other fisheries that target or incidentally catch DSR. The commercial DSR fishery was closed in 2005 due to high catch in the recreational sector. As well, an estimate of absolute abundance was available in the DSR fishery, calculated using fishery-independent data collected from submersible surveys of DSR abundance and habitat. Methods of stock assessment and management in the DSR fishery may not be feasible in KS^n fisheries due to a general lack of data and the inability to exclude a user-group.

Some characteristics of invertebrate fisheries inherently resulted in fewer stock assessment and management challenges, compared to finfish. For example, the species captured in invertebrate fisheries were not susceptible to barotrauma, most were targeted in single-species fisheries, and none were taken as bycatch. Furthermore, for abalone and geoduck fisheries, stock assessment via direct observation is relatively straightforward because these species are sessile and prefer relatively shallow depths. With the exception of the DSR fishery, all of the model fisheries that targeted species susceptible to barotrauma were considered relatively unsustainable. Even in the presence of multiple user-groups, discard mortality would be lower if the targeted species were not susceptible to barotrauma.

Due to low stock productivity typically associated with KS^n fisheries, it was reasonable to assume that there is a time-lag between implementation of management methods and a corresponding change in the status of a fishery. In other words, a fishery may be rebuilding under methods of management that did not result in the overfished state. For example, catch rates declined in the VRL fishery from the 1950s until the early to mid-1990s, and have since remained

stable or have increased (Anon 2003). The recent improvement in catch rates was concurrent with implementation of relatively sophisticated methods of stock assessment and management,

(Musick 1999), although they are highly fecund (Haldorson and Love 1991). Size-at-age and age-at-maturity of yelloweye rockfish (*Sebastes rubberimus*) has been shown to vary with latitude, presumably resulting from lasting effects of differential fishing pressure (Kronlund and Yamanaka 2001; Yamanaka and Lacko 2001). Species of inshore rockfish are assumed to undertake only limited migration after recruitment (Gunderson 1997), and therefore planktonic larval propagules are assumed to be the principal means of repopulating depleted areas.

3.3. Current management system and challenges

As a KS^n fishery, the use of traditional approaches of fisheries stock assessment and management leave inshore rockfish particularly susceptible to overfishing. Factors limiting the efficacy of stock assessment methods for inshore rockfish include:

(i) the use of fishery catch-per-unit-effort (CPUE) to index population trends and to detect disproportionate depletion within management areas;

(ii) variation in management strategies

small scale. Assignment of user-rights has also eliminated the tragedy of the commons effect. In general, a TURF works to address the sustainability criteria. For this reason, the following section describes the form of TURF employed in the CL fishery and then determines if the IR fishery may be structured as a TURF.

3.4.1. Co-operative management

ócommand and controlô management assumes that resource management problems are well-bounded, clearly defined, relatively simple, and often linear with regard to cause and effect (Holling and Meffe 1996). Co-management is in direct opposition to command and control management, which often results in undesired consequences in terms of sustainability (Holling and Meffe 1996). Co-management involves projects at a local level and stewardship with a high degree of community involvement that actively involves resource users in decision-making, and fosters communication between stakeholders, empowers users in resource management, and incorporates knowledge from more sources than conventional management (Pinkerton 1989, 1994; Berkes et al. 2001; Defeo and Castilla 2005). Co-management implies local fishing access rights and as such increases fisher incentive for resource sustainability, working in opposition to command and control management (Pinkerton 1989; Ostrom et al. 1994; Baland and Platteau 1996; Lane and Stephenson 2000; Dietz et al. 2003; Pomeroy and Rivera-Guieb 2005).

3.4.2. Territorial use rights fisheries (TURFs)

Fishing access rights are the central element of a TURF (Christy 1982), which is a form of community-based co-management where access rights to engage in fishing in a particular geographical location are assigned to stakeholders (e.g., individuals, groups, governments). As noted in Christy (1982), TURFs increase user-rights and limit capital and labour to the point where greatest net benefits are produced, and therefore avoid a tragedy of the commons by conferring a level of resource ownership to the user. TURFs are most effective where specificity

should (1) be large enough so that harvesting outside of the area does not significantly diminish the value of use within the area. If the entire IR fishery were structured as a TURF, spawning biomass should be kept above a permitted level (a lower reference point) in all areas, thus allowing recruitment from source areas that may be outside of the managed area(s). Because of the uncertainty of IR movement and population structure, delineating TURF areas in the IR fishery may be challenging. However, similar to the selection of existing Rockfish Conservation Areas (RCAs), delineation of areas could be accomplished through the combined traditional ecological knowledge of recreational, commercial, and aboriginal harvesters, and with existing fishery-dependent and independent data.

Regulations in each management area in the IR fishery should be (2) monitored closely and protected by overarching federal laws. This is possible using existing electronic monitoring technology as required by Fisheries and Oceans Canada (DFO). Areas of the present IR fishery are in remote locations, and the fishery takes place in a large geographical area compared to traditional TURFs. As such, fishers may not live near their fishing grounds, which may limit the use of methods of enforcement and monitoring used in traditional TURFs. Electronic monitoring is already used most Canadian groundfish fisheries and the applicability of using electronic monitoring to manage IR fishery as a TURF should be considered (Ames et al. 2007).

Areas of the IR fishery should also (3) be clearly demarcated and identifiable. This would also be possible using modern navigational and charting equipment and mapping software provided by electronic monitoring, as is sustainable with delineating areas of the IR fishery which are currently closed to fishing.

IR are relatively sedentary, and as such (4) possess the requisite biological characteristics to be managed as a TURF. However, because of the presence of both a recreational and First Nations fishery, it is uncertain whether (5) cultural conditions that permit acquisition of exclusive user rights are present in the fishery. Cultural factors may be taken into account by allowing

One of the primary management challenges in the IR fishery is the absence of a reliable index of stock size, which arises mainly from the suite of stock assessment challenges (Yamanaka and Lacko 2001). Structuring the IR fishery as a TURF would address more fundamental issues regarding common property resources and user-rights, as explained above. A TURF may eventually allow more data-intensive and sustainable management methods such as those employed in the NZRL and CL fisheries. For instance, the use of fishery-dependent data as a primary source of indexing stock status was sustainable in some KS^n fisheries, in particular, the relatively data-rich NZRL fishery where harvest control rules and reference points were based on CPUE data from the fishery.

4. CONCLUSION

Despite substantial challenges in KS^n fisheries, relative sustainability/success has been achieved in several situations. Partly due to fishery, site, and species-specific characteristics, each of the model fisheries implemented the seven sustainability criteria to varying degrees. Fisheries that implemented the criteria to a higher degree were in general more sustainable.

The IR fishery requires a unique method of management to address each of the criteria. The single most challenging aspect of applying the criteria of each candidate model fishery to the IR fishery was the lack of fisher incentive for resource sustainability, stemming from the absence of sufficient user-rights. For this reason, it was determined that a system of governance based on user-rights, specifically a TURF, could potentially improve management of the IR fishery. The CL fishery shares many similarities with the IR fishery, and was structured as a TURF to recover from overfishing. Since structuring as a TURF, the CL fishery has improved considerably as fundamental concerns regarding common property resources and user-rights were addressed. Structuring the IR fishery as a TURF may benefit from the existing IVQ system, an existing network of RCAs, and a comprehensive monitoring system which could improve data collection to permit more specific stock assessment and a prospective evaluation of harvest and management strategies, which have proven quite sustainable in the NZRL fishery.

Several limitations of this study were provided. Most notably was the confounding between the seven criteria, effecting the interpretation of whether sustainability of each fishery was related to the level of incorporation of each criterion. Also, due to access of information, the selection of model fisheries was limited in number and to fisheries in relatively developed nations. A worthwhile extension of this study should include more model fisheries and should concentrate on species with a narrower scope of spatial and life-history characteristics.

This study developed a valuable framework to compare sustainability between fisheries and was an effective tool

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Table 1: 'Model fisheries' reviewed in this study and their abbreviations.

Pagrus auratus		
Glaucosoma hebraicum		
Sebastes spp.		
Epinephelus itajara		
Sebastes levis		
Sebastes spp.		
Jasus edwardsii)		*Sagmariasus verreauxi*
Panulirus cygnus		
Jasus edwardsii		
Strongylocentrotus franciscanus		
Panopea abrupta		
Haliotis rubra	*Haliotis laevigata*	
Oncholepas concholepas		

Table 2: Biological status of each model fishery.

Table 3: Summary of the major regulatory strategies employed in each model fishery.

Table 4: **Overview of each model fishery in the context of criteria one to three of fishery management success.**

Table 5: Overview of each model fishery in the context of criteria four to seven of fishery management success.

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Table 6:

Table 7: Summary of literature review and synthesis of KS^n fisheries regarding how each criteria of fishery management success may permit or impede the applicability of relatively successful/sustainable management tactics for the IR fishery.