

**WebPanel 1. Materials and methods**

Additional information on materials and methods used for the analysis is presented here.

**Selection of case studies**

The literature search was semi-structured. Initially, we undertook a search of the ISI Web of Knowledge database, using the key words: ITQ, IFQ, individual fishing quota, fishing privilege, fish OR fishery. Journal articles that analyzed fisheries in which tradable rights-based management systems had been applied, and that were published since the year 2000 (inclusive) and up to the beginning of 2011, were then selected for review. Where the selected papers referred to additional articles that had not been identified in the initial search, these were investigated and included where appropriate. In this manner, any trail of relevant references was followed either until it stopped or back to the year 2000, whichever occurred first. The search identified 46 references analyzing 51 case studies. The full list of references is included in WebTable 2.

**Characterization of the issues considered in the case studies**

We recorded information relating to the issues considered in each case study using three alternative sets of descriptors: “A”, “A’”, and “B”. Descriptor “A” allowed for the greatest amount of information to be recorded. It detailed whether the issue was addressed qualitatively or quantitatively, and then whether the reported response was in line with (+) or counter to (–) certain a priori expectations associated with ITQ management systems. The second descriptor, “A’”, is a restricted version of “A”, in that only the manner in which the issue was considered was recorded (ie quantitatively or qualitatively). This type of descriptor was applied in cases where potential responses to the issue were broad and consequently difficult to anticipate and clearly define. The third type of descriptor, “B”, recorded a yes/no response to the question posed under the issue description. These were used with issues for which a priori expectations with respect to the outcome are clearer than the “A” cases (and were subsequently recoded as [+] or [–] in Table 2, as for descriptors of type “A”) but clear metrics with which to measure the actions were not obvious (eg M-I: Measures to explicitly avoid concentration). By definition, the responses captured within the “B” descriptors are all qualitative in nature.

For all the descriptors, if an issue was not considered in the case study, no response was recorded and resulted in the empty spaces seen in Table 2. The definition of issues considered within each of the broad impact domains is provided in WebTable 1.

**Summary description of the data**

WebFigure 1 presents the proportion of case studies in which individual issues were considered. With the exception of the decrease in active vessel numbers (E-7), which was considered in two-thirds of the case studies, none of the issues were considered in more than half of the case studies, and 90% of the issues were considered in less than a third of the case studies. The proportion of issues considered across studies was much lower when considering only the cases in which quantification of these issues was attempted. With the exception of the decrease in active vessel numbers, quantification of issues was attempted in at most 25% of the case studies, and often much more infrequently. This confirms that the methods for carrying out integrated empirical assessments of the impacts of catch share systems are still largely being developed. There did not seem to be an established set of variables across impact domains that was used as a basis to carry out the assessments and would allow comparisons to be made across case studies. Economic impacts, such as strategies to maximize revenue (landing higher value fish) or reduce cost (improving fleet efficiency), seem to be those that lend themselves most frequently to quantification, along with some issues related to the operation of the quota system.

Most (90%) of the case studies addressed less than a third of the issues identified in the review, and only half of the studies attempted to address more than one in six of the issues, either qualitatively or quantitatively. None of the studies attempted to develop quantified approaches to more than one in four of the issues they considered. This is probably because most of the recently published studies on the quantification of a particular impact of the ITQ system seemed to focus on developing methods to quantify this particular impact, rather than using a more comprehensive assessment approach.

**Statistical analysis**

Principal components analysis, a dimension reduction technique (Mardia et al. 1979), was applied to the data to characterize the diversity of publications in the six impact domains (ie Economic, Quota, Biology, Interactions, Stewardship, and Management), using R (R Development Core Team 2012). The case study data are first represented as a matrix of quantitiveness scores, with rows corresponding to the 51 case studies and columns to the 50 issues. The scores are assigned a value of 2 if the issue is addressed quantitatively, 1 if addressed qualitatively, and 0 if not addressed. We then construct a  $5 \times 6$  matrix  $X$  of group averages, such that matrix element  $X_{rd}$  is the average score in impact domain  $d$  for reference  $r$  and assumes values between 0 and 2. Averaging within impact domains attributes equal weight to the domains rather than to the issues within a particular domain, thus counteracting a skewing toward domains (eg economic impacts) in which a larger number of issues are considered.

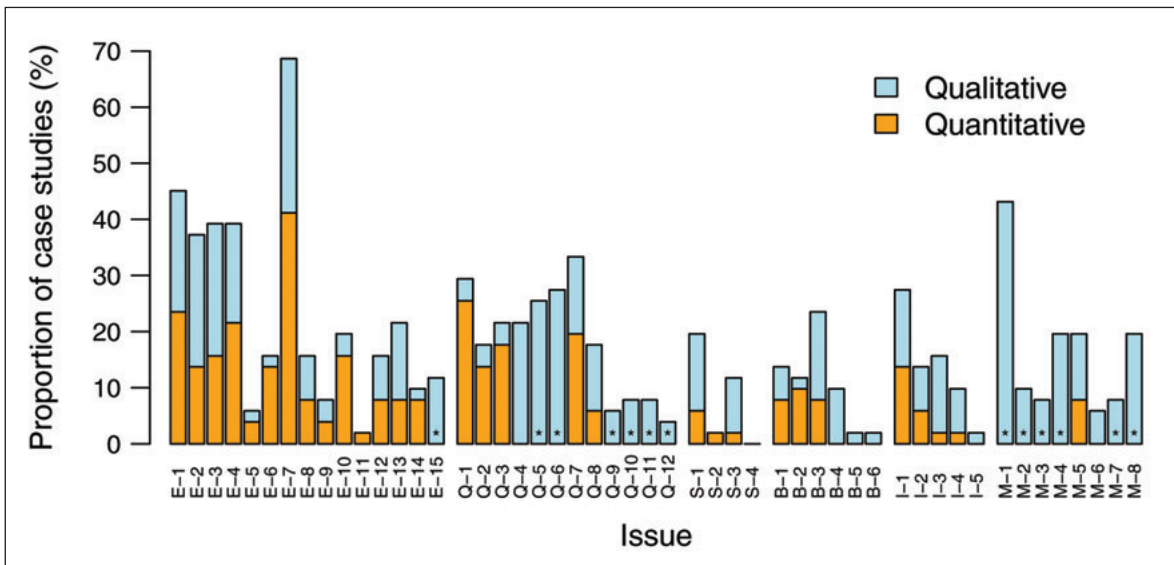
Regarding each reference as a point in a 6-dimensional Euclidean space, we applied hierarchical clustering using complete linkage to group similar references together. A visual appraisal of the dendrogram suggested seven clusters that provided a reasonable clustering.

Applying principal components analysis to  $X$  allows one to see the main features in the data by focusing on the first few principal components. The first three principal components (WebFigure 3) account for 72% of the variation. Such biplots (Gabriel 1971) show both the reference scores (labels colored by cluster) and the loadings of the original domain variables (arrows) in the principal components. The arrows show the degree of association between the case studies and the impact domain scores. For instance, the orange cluster (and to a lesser extent the light blue cluster) is strongly associated with the analysis of quota systems, whereas the blue–green cluster associates more with the evaluation of economic impacts, and the dark green with biological impacts and stewardship. The case studies 46 and 47 score high in most domains, whereas the large set of case studies in the dark blue cluster have a low overall level of quantitiveness. The light green cluster (22, 25) scores relatively high with respect to assessing the impacts on management; since this variable aligns mainly with principal component 5, proximity of these references is not evident on the projections presented here.

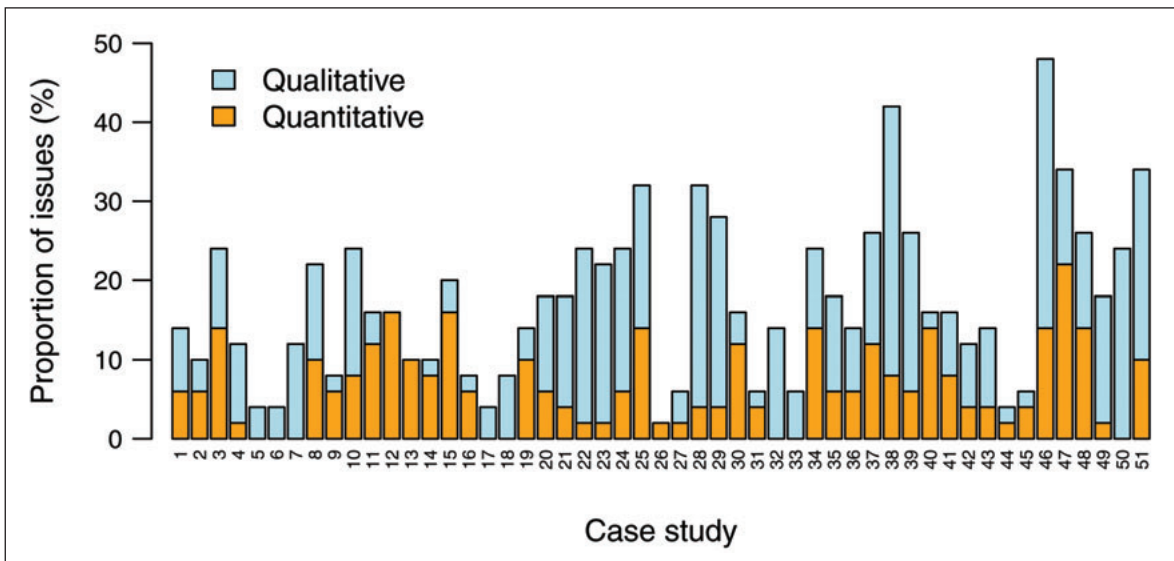
Among the studies with higher levels of quantitative assessment, there appear to be three possible directions that assessments have followed, with studies having a strong focus on either biological impacts, economic consequences of ITQs, or the functioning of the quota market. Interestingly, while there appears to be a correlation between the efforts made to quantify biological impacts and the stewardship effects of ITQs, studies which have focused on these domains achieve weak scores regarding the measurement of economic impacts. Interactions between fishers and other stakeholders and how these may be affected by ITQs seem to be considered mainly in association with the way in which the quota system operates.

**WebTable 1. Description of issues identified in the case studies**

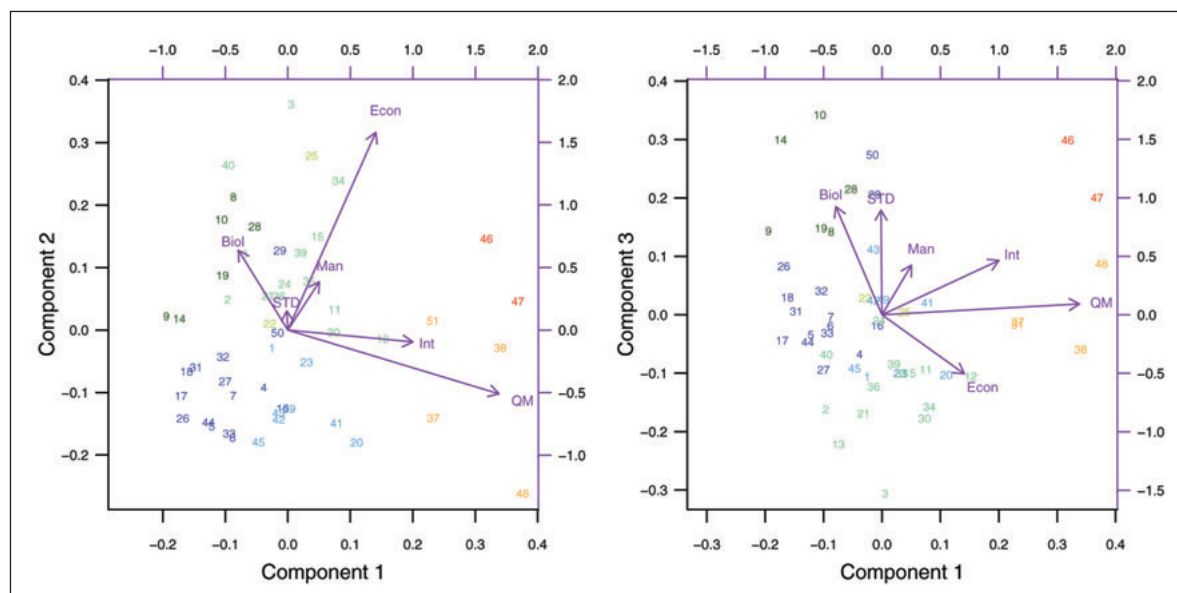
<i>Label</i>	<i>Variable description</i>	<i>Descriptor</i>
E-1	Revenue maximizing strategies?	A
E-2	Cost reducing strategies?	A
E-3	Improved fishery rents?	A
E-4	Improved fleet efficiency?	A
E-5	Change in spatial distribution of effort with vessels fishing closer to home port?	A
E-6	Extension of the fishing season?	A
E-7	Reduction in number of active fishing vessels?	A
E-8	Influence of social networks	A'
E-9	Strategic behavior prior to quotas being established?	A
E-10	Decrease in employment (number of jobs)?	A
E-11	Maintenance of job-days?	A
E-12	Increased average crew remuneration?	A
E-13	Increase in average size of fishing vessels (drop-out of smaller boats)?	A
E-14	Reduced crew share as proportion to gross revenue and inclusion of lease costs in shared costs?	A
E-15	Consideration of opportunity costs of remaining in the fishery?	B
Q-1	Increase in quota leasing with time?	A
Q-2	Decrease in permanent quota sales after initial buyout?	A
Q-3	Development of an investor component in the fishery?	A
Q-4	Increased difficulty of access for newcomers?	A
Q-5	Quota (permanent) sale price information recorded/available?	B
Q-6	Quota leasing price information recorded/available?	B
Q-7	Concentration of quota ownership (horizontal integration of quota owners)?	A
Q-8	Increase in vertical integration?	A
Q-9	Is there a problem of market power in the quota trades?	B
Q-10	Influence of tax/fiscal policies on quota trading patterns?	B
Q-11	Description of the quota trading system?	B
Q-12	Quota price dispersion reported?	B
S-1	Improved compliance?	A
S-2	Is there freeriding by associated fleets?	A
S-3	Support for long-term conservative management?	A
S-4	Engagement with accreditation strategies?	A
B-1	Highgrading (discarding of lower for higher value catch) of target species?	A
B-2	Increased bycatch and discard of associated species?	A
B-3	Positive impacts on target stocks?	A
B-4	Positive impacts on associated stocks?	A
B-5	Positive impact on threatened, endangered, and protected species?	A
B-6	Positive impacts on habitat?	A
I-1	Interactions with processors	A'
I-2	Interactions with quota brokers	A'
I-3	Interactions with recreational fishers	A'
I-4	Interactions with Aboriginal groups	A'
I-5	Interactions with non-governmental organizations	A'
M-1	Measures to explicitly avoid concentration of quota ownership/catch?	B
M-2	Additional regulations to limit environmental externalities?	B
M-3	Revision of initial quota allocations?	B
M-4	Change in monitoring and enforcement strategies?	B
M-5	Increased costs of monitoring, enforcement, and administration?	A
M-6	Increased costs of assessment?	A
M-7	Additional capacity reduction measures?	B
M-8	Cost sharing/recovery?	B



**WebFigure 1.** Proportion (% of total number) of case studies in which individual issues are considered in qualitative or quantitative terms. Purely qualitative issues (descriptor "B") are marked with an asterisk.



**WebFigure 2.** Proportion (% of total number) of issues considered, in qualitative or quantitative terms for each case study.



**WebFigure 3.** Biplots of the first and second (left) and the first and third (right) principal components of the average score matrix  $X$ . References are denoted by number, with color representing cluster from hierarchical clustering and matching the colors used in Table 2. The purple arrows denote the variable loadings; effectively they are projections of the original variable axes into the plane of the two displayed principal components.

#### ■ WebReferences

Gabriel KR. 1971. The biplot graphical display of matrices with applications to principal component analysis. *Biometrika* 58: 453–67.

Mardia KV, Kent JT, and Bibby JM. 1979. *Multivariate analysis*. London, UK: Academic Press.

R Development Core Team. 2012. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. ISBN 3-900051-07-0; [www.R-project.org](http://www.R-project.org). Viewed 14 Sep 2012.

**WebTable 2. Case studies included in the review**

Author(s)	Year	Title	Journal	Case study	Case study #
Asche F, Eggert H, Gudmundsson E, <i>et al.</i>	2008	Fisher's behaviour with individual vessel quotas—over-capacity and potential rent: five case studies	<i>Mar Policy</i> <b>32</b> : 920–27	Iceland, large trawl; UK, trawl	1, 2
Abbott J, Garber-Yonts B, and Wilen JE	2010	Employment and remuneration effects of IFQs in the Bering Sea/ Aleutian Islands crab fisheries	<i>Mar Resour Econ</i> <b>25</b> : 333–54	Alaska, crab	3
Batstone CJ and Sharp BMH	2003	Minimum information management systems and ITQ fisheries management	<i>J Environ Econ Manag</i> <b>45</b> : 492–504	New Zealand, snapper	4
Bess R	2001	New Zealand's indigenous people and their claims to fisheries resources	<i>Mar Policy</i> <b>25</b> : 23–32	New Zealand, fisheries	5
Borch T	2010	Tangled lines in New Zealand's uota management system: the process of including recreational fisheries	<i>Mar Policy</i> <b>34</b> : 655–62	New Zealand, fisheries	6
Bradshaw M	2004	A combination of state and market through ITQs in the Tasmanian commercial rock lobster fishery: the tail wagging the dog?	<i>Fish Res</i> <b>67</b> : 99–109	Tasmania, rock lobster	7
Branch TA	2006	Discards and revenues in multi-species groundfish trawl fisheries managed by trip limits on the US west coast and by ITQs in British Columbia	<i>B Mar Sci</i> <b>78</b> : 669–89	Canada, west coast groundfish trawl	8
Branch TA and Hilborn R	2008	Matching catches to quotas in a multispecies trawl fishery: targeting and avoidance behavior under individual transferable quotas	<i>Can J Fish Aquat Sci</i> <b>65</b> : 1435–46	Canada, west coast groundfish trawl	9
Branch TA, Rutherford K, and Hilborn R	2006	Replacing trip limits with individual transferable quotas: implications for discarding	<i>Mar Policy</i> <b>30</b> : 281–92	British Columbia, groundfish	10
Brandt S	2005	The equity debate: distributional impacts of individual transferable quotas	<i>Ocean Coast Manage</i> <b>48</b> : 15–30	Surf clam	11
Brandt S	2007	Evaluating tradable property rights for natural resources: the role of strategic entry and exit	<i>J Econ Behav Organ</i> <b>63</b> : 158–76	Surf clam	12
Brandt S and Ding N	2008	Impact of property rights on labor contracts in commercial fisheries	<i>Ocean Coast Manage</i> <b>51</b> : 740–48	Surf clam	13
Bremner G, Johnstone P, Bateson T, and Clarke P	2009	Unreported bycatch in the New Zealand West Coast South Island hoki fishery	<i>Mar Policy</i> <b>33</b> : 504–12	New Zealand, fisheries	14
Campbell D, Brown D, and Battaglene T	2000	Individual transferable catch quotas: Australian experience in the southern bluefin tuna fishery	<i>Mar Policy</i> <b>24</b> : 109–17	Southern blue tuna	15

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**WebTable 2. Case studies included in the review – *continued***

<i>Author(s)</i>	<i>Date</i>	<i>Title</i>	<i>Journal</i>	<i>Case study</i>	<i>Case study #</i>
Carothers C, Lew DK, and Sepez J	2010	Fishing rights and small communities: Alaska halibut IFQ transfer patterns	<i>Ocean Coast Manage</i> <b>53</b> : 518–23	Alaska, halibut	16
Castilla JC	2010	Fisheries in Chile: small pelagics, management, rights, and sea zoning	<i>B Mar Sci</i> <b>86</b> : 221–34	Chile, pelagic fleet	17, 18
Chavez C, Gonzalez N, and Salgado H	2008	ITQs under illegal fishing: an application to the red shrimp fishery in Chile	<i>Mar Policy</i> <b>32</b> : 570–79	Chile, red shrimp	19
Connor R and Alden D	2001	Indicators of the effectiveness of quota markets: the south east trawl fishery of Australia	<i>Mar Freshwater Res</i> <b>52</b> : 387–97	Australia, southeast trawl fishery	20
Dawson R	2006	Vertical integration in the post-IFQ halibut fishery	<i>Mar Policy</i> <b>30</b> : 341–46	US, halibut	21
Dupont DP and Grafton RQ	2000	Multi-species individual transferable quotas: the Scotia–Fundy mobile gear groundfishery	<i>Mar Resour Econ</i> <b>15</b> : 205–20	Scotia–Fundy, mobile gear groundfishery	22
Eythorsson E	2000	A decade of ITQ-management in Icelandic fisheries: consolidation without consensus	<i>Mar Policy</i> <b>24</b> : 483–92	Iceland, large trawl	23
Ford W	2001	Restructuring the Tasmanian rock-lobster fishery – the effect of two years of management under individual transferable quotas	<i>Mar Freshwater Res</i> <b>52</b> : 1641–48	Tasmania, rock lobster	24
Grafton RQ, Squires D, and Fox KJ	2000	Private property and economic efficiency: a study of a common-pool resource	<i>J Law Econ</i> <b>43</b> : 679–713	British Columbia, halibut	25
Haraldsson G	2008	Impact of the Icelandic ITQ system on outsiders	<i>Aquat Living Resour</i> <b>21</b> : 239–45	Iceland	26
Hernández A and Dresdner J	2010	The effect of temporal closures and individual quotas on fishing trip duration: a hazard function analysis	<i>Appl Econ</i> <b>42</b> : 3767–76	Chile, pelagic fleet	27
Holland DS	2000	Fencing the fisheries commons: regulatory barbed wire in the Alaskan groundfish fisheries	<i>Mar Resour Econ</i> <b>15</b> : 141–49	Alaska, groundfish	28
Khan A	2006	Sustainability challenges in the geoduck clam fishery of British Columbia: policy perspectives	<i>Coast Manage</i> <b>34</b> : 443–53	British Columbia, geoduck	29
Kompas T and Che TN	2005	Efficiency gains and cost reductions from individual transferable quotas: a stochastic cost frontier for the Australian south east fishery	<i>Prod Anal</i> <b>23</b> : 285–307	Australia, southeast trawl fishery	30
Kulmala S, Peltomaki H, Lindroos M, <i>et al.</i>	2007	Individual transferable quotas in the Baltic Sea herring fishery: a socio-bioeconomic analysis	<i>Fish Res</i> <b>84</b> : 368–77	Baltic Sea, herring	31
Mansfield B	2006	Assessing market-based environmental policy using a case study of North Pacific fisheries	<i>Global Environ Chang</i> <b>16</b> : 29–39	Alaska, pollock	32

*continued*

**WebTable 2. Case studies included in the review – continued**

Author(s)	Date	Title	Journal	Case study	Case study #
Matthiasson T	2008	Rent collection, rent distribution, and cost recovery: an analysis of Iceland's ITQ catch fee experiment	<i>Mar Resour Econ</i> <b>23</b> : 105–17	Iceland, ITQ system	33
Matulich SC	2008	Did processing quota damage Alaska red king crab harvesters? Empirical evidence	<i>Mar Resour Econ</i> <b>23</b> : 253–71	Alaska, crab	34
Matulich SC and Clark M	2003	North Pacific halibut and sablefish IFQ policy design: quantifying the impacts on processors	<i>Mar Resour Econ</i> <b>18</b> : 149–66	US, halibut; Alaska, sablefish	35, 36
Newell RG, Sanchirico JN, and Kerr S	2005	Fishing quota markets	<i>J Environ Econ Manag</i> <b>49</b> : 437–62	New Zealand, fisheries	37
Pinkerton E and Edwards DN	2009	The elephant in the room: the hidden costs of leasing individual transferable fishing quotas	<i>Mar Policy</i> <b>33</b> : 707–13	British Columbia, halibut	38
Repetto R	2001	A natural experiment in fisheries management	<i>Mar Policy</i> <b>25</b> : 251–64	Canada, East Coast scallop	39
Sigler M and Lunsford C	2001	Effects of individual quotas on catching efficiency and spawning potential in the Alaska sablefish fishery	<i>Can J Fish Aquat Sci</i> <b>58</b> : 1300–12	Alaska, sablefish	40
Stewart J and Callagher P	2011	Quota concentration in the New Zealand fishery: annual catch entitlement and the small fisher	<i>Mar Policy</i> <b>35</b> : 631–46	New Zealand, inshore, middle-depth, and deepwater fisheries	41, 42, 43
Stewart J and Walshe K	2008	Compliance costs and the small fisher: a study of exiters from the New Zealand fishery	<i>Mar Policy</i> <b>32</b> : 120–31	New Zealand, fisheries	44
Stewart J, Walshe K, and Moodie B	2006	The demise of the small fisher? A profile of exiters from the New Zealand fishery	<i>Mar Policy</i> <b>30</b> : 328–40	New Zealand, fisheries	45
Turriss BR	2009	A rejoinder to E Pinkerton <i>et al.</i> , the elephant in the room: the hidden costs of leasing individual transferable fishing quotas	<i>Mar Policy</i> <b>34</b> : 859–67	British Columbia, halibut	46
van Putten I and Gardner C	2010	Lease quota fishing in a changing rock lobster industry	<i>Mar Policy</i> <b>34</b> : 859–67	Tasmania, rock lobster	47
van Putten I, Hamon KG, and Gardner C	2011	Network analysis of a rock lobster quota lease market	<i>Fish Res</i> <b>107</b> : 122–30	Tasmania rock lobster	48
Vetemaa M, Eero M, and Hannesson R	2002	The Estonian fisheries: from the Soviet system to ITQs and quota auctions	<i>Mar Policy</i> <b>26</b> : 95–102	Estonia, fisheries	49
Yandle T	2006	The Challenger Scallop Enhancement Company: collaborative management of a natural resource based in the private sector	<i>Public Admin Rev</i> <b>66</b> : 148–50	New Zealand, southern scallop	50
Yandle T and Dewees CM	2008	Consolidation in an individual transferable quota regime: lessons from New Zealand, 1986–1999	<i>Environ Manage</i> <b>41</b> : 915–28	New Zealand, fisheries	51