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A comparison between industry and observer catch compositions within the Gulf of Alaska rockfish fishery

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Stock assessment scientists and fishery managers operate under the necessary assumption that the identities of species in official catch reports are known without error. To test this assumption, the incidence, magnitude, and possible causes of species misidentification between industry and fishery-observer data sources were investigated for 29 rockfish landings made in Kodiak, AK. Rockfish species were misidentified in nearly all these landings, and the incidence of misidentification between data sources differed among species rather than the processing plant examined. Although observers failed to identify species recorded by processing plant staff as a result of small sampling fractions, the industry missed species that were identified by observers in more than half the offloads examined. The presence of management species complexes did not reduce the likelihood of erroneous quota debiting as a result of species misidentification. In one landing, the misidentification of the main rockfish species corresponded to the release of a weekly report on total allowable catch and resulted in a delayed fishery closure. Efforts to improve the accuracy of species identifications reported by industry in landing reports are warranted in Alaska, and methods to accomplish this through efficient deployment of observers are discussed.

Keywords: compliance monitoring, fisheries management, fishery observers, species identification.

Introduction

The effective management of fishery resources depends on the accurate accounting of removals. In mature fisheries with robust observer programmes, considerable effort can be expended by observers to gather detailed information on the quantity, disposition, and characteristics of the catch. Dispositions include the retained and discarded portions, and catch characteristics can include size, age (through, e.g., otolith collection), ecological niche (through the study of stomach contents), and parent stock (through genetic analyses of soft tissues) of individual fish. For any of this information to be useful for assessors and fishery managers, species must be correctly identified. Yet, despite growing global concern over the mislabelling of seafood (e.g. Jacquet and Pauly, 2008), it is often taken for granted that the identity of the species recorded by industry and fishery observers are correct and without error.

Rockfish are slow-growing and long-lived and are especially vulnerable to overfishing (Parker *et al*., 2000). In Alaska, rockfish harvests have been statewide since the early 1900s, peaking at 510 000 t in 1965, and declining precipitously thereafter (Bracken, 1986). It is known that most historical landings of rockfish were taken by trawl gear within the Gulf of Alaska region (defined as the area between longitudes 154 and 159°W), but it was not until the establishment of an observer programme in 1973 that the species identity of catches could be reported with confidence (Bracken, 1986). Today, rockfish are still harvested primarily by trawl in the Gulf of Alaska, and >37 species of rockfish are defined in observer training manuals (AFSC, 2010).

In 2006, the National Marine Fisheries Service (NMFS) drafted a comprehensive programme to limit access privileges; it became known as the Rockfish Pilot Project (RPP) and aimed at ending the "race for fish" in the central Gulf of Alaska. The RPP facilitated the formation of fishing cooperatives with guaranteed quota allocations for vessels targeting Pacific ocean perch (POP; *Sebastes alutus*), northern rockfish (*S. polyspinis*), and pelagic shelf rockfish (a species complex which includes dusky rockfish *S. variabilis*, yellowtail rockfish *S. flavidus*, and widow rockfish *S. entomelas*). Originally designed as a short-term (5-year) programme to learn lessons for future management initiatives, the RPP began in 2007 and continues today (NMFS, 2011a). Fishing vessels without on-board processing facilities must deliver and offload their catch to a shore-based processing plant. For catcher vessels <38.1 m (125 ft) overall length, such as those within the RPP, the retained-catch data used in the NMFS catch accounting system are almost entirely based on industry landing reports (also known as "fish tickets"), which are created for each delivery (Cahalan *et al*., 2010). The RPP prohibits each cooperative from exceeding their allocated quotas for various species and complexes. Hence, there may be an incentive to intentionally misidentify some species on landing reports by RPP participants if, for example, the total allowable catch (TAC) of one species within the cooperative's quota is in jeopardy of being exceeded (so closing the fishery), while that of a similar but different species is not. There may also be unintentional misidentification as rockfish species can look similar even to trained personnel (see ftp://ftp.afsc.noaa.gov/posters/pJOrr02_rockfishes-of-ak.pdf). For these reasons, one requirement of the RPP is that industry staff at processing plants need to identify, sort, and weigh by species the landings made by participating catcher vessels that have 100% at-sea observer coverage.

Because of concerns about the veracity of industry-reported species identifications, a pilot project was conducted by the NMFS to compare rockfish catch compositions derived from fishery observers stationed shoreside at processing plants with those reported on industry catch reports. The objective was to quantify mismatches in rockfish between data sources and to determine whether they differed widely among species, processing plants, observers, or seasons. Such comparisons are crucial to understanding the accuracy of industry data within the RPP and are relevant for fishery monitoring within future quota-allocation programmes anticipated to be implemented in the United States.

Methods

Data treatment

Industry and observer data were compared from catcher-vessel rockfish landings at five shoreside processing plants in Kodiak, AK. Kodiak is one of the most active US ports in terms of the quantity and value of commercial landings (NOAA, 2009). The observer protocol was to collect a sample of 100 rockfish from one randomly determined delivery each day, identify fish by species, and obtain the total weight of each species in the sample. The industry data consisted of the species-specific landed weights and the disposition code (whole fish, headed and gutted, discarded at sea, or onshore), all dated from the landing reports. Only the rockfish information from landing reports was of interest. Rockfish that were either discarded or not whole fish were vetted from industry sources because the observer would not have had an opportunity to sample those components.

Statistical tests on individual species were not always possible. Where appropriate, data were aggregated into species complexes corresponding to the management units defined by the NMFS in 2004. These include (i) shortraker/rougheye (consisting of shortraker rockfish, *S. borealis*, and rougheye rockfish, *S. aleutianus*), (ii) thornyhead rockfish (*Sebastolobus alascanus*), (iii) pelagic shelf rockfish, (iv) demersal shelf rockfish (yelloweye rockfish, *S. ruberrimus*, and rosethorn rockfish, *S. helvomaculatus*, among others), and (v) other slope rockfish (including redbanded rockfish, *S. babcocki*, sharpchin rockfish, *S. zacentrus*, and harlequin rockfish, *S. variegatus*). Black rockfish (*S. melanops*) were included in the pelagic shelf rockfish group because they are similar to dusky rockfish (*S. variabilis*, a pelagic shelf rockfish), and because management of both species has recently been transferred to the Alaska Department of Fish and Game. The term "species" is used in the following text to refer both to individual species and those aggregated into complexes.

Analytical approach

Although limited observer data were available throughout the entire year, the data analysed were constrained to those collected during July, when 98% of the total rockfish weight collected by observers was landed. Scaled observer estimates for rockfish species i ($\hat{W}_i$) were derived for each landing by multiplying its weight proportion in the observer sample by the total weight on the landing report, for comparison with W_i, the same species weight measured by processing plant staff. Therefore, the difference $D_i = W_i - \hat{W}_i$ is positive when industry reports greater weights than observers, and *vice versa*. Observer and industry pairs of records for each species, delivery, and plant are hereafter termed cases.

Comparisons between industry and observer data were made under the assumption used in management of the fishery that observers identify species correctly. Support for this assumption comes from the fact that unlike industry personnel, observers are identically trained and must pass a standardized fish-identification test to achieve NMFS certification. Also, the data for this project were provided by three experienced observers. The observer rockfish-identification protocols follow Orr *et al.* (2000), Orr and Blackburn (2004), and Orr and Hawkins (2008).

All statistical tests described below were two-sided and performed with a significance level of 0.05 using the R programming language (R version 2.11.0; R Development Core Team, 2010). As not all species groups were found within each processing plant, species–plant interactions were not examined. Comparisons aimed to determine whether misidentifications between industry and observer data were the result of non-random factors were framed within hypotheses (H; see sections below). Two null hypotheses are posed to test whether differences in relative rockfish weights exist when (i) both industry and observer sources identified the same species, and (ii) only one of these sources identified a species. Three alternatives to the second null hypothesis are explored.

$H_0$1: The catch proportions of the same species are not different between data sources among processing plants and/or species

In cases where both data sources identified the same species, linear regression was used to test whether the relationship between the observer and industry catch of species i (expressed as weight proportions in the total landing) was significantly different from a line with a slope of one and an intercept of zero (i.e. perfect agreement). Comparisons of these relationships were made among processing plants and species; significant departure from the expected relationship was interpreted as support to reject $H_0$1.

$H_0$2: Rockfish misidentification does not differ among processing plants and/or species

Within each landing, each species should be present within the observer and industry datasets. If only one data source identified a particular species i, a zero or null value existed for the other data source. Such mismatched cases were labelled as either industry- or observer-only identifications. The proportion of industry- or observer-only identifications within each processing plant was calculated and compared for equality among plants and species separately using χ^2 tests. Deviation from equality was interpreted as grounds for rejecting $H_0$2.

H2a: Industry-only rockfish identifications resulted from small observer-sampling fractions

Industry-only identifications may have arisen because the observer failed to detect a species in their sample that was present in the landing. This could be a consequence of the rarity of the species and/or too small a sample. For each species of rockfish in a landing, the hypergeometric distribution was used to determine the probability of drawing a zero (P_0) from the total delivery weight given a random observer's sample weight and the species' weight in the delivery. A Welch two-sample t-test for means was used to compare the central tendency of P_0 values found in cases where the species was present in (i) only industry-reported landings, and (ii) both the landings and the observer samples. A significantly lower mean value from the second condition compared with the first supports acceptance of *H*2a. P_0 values from industry-only cases were also tested for homogeneity among processing plants and species separately, using the Kruskal–Wallis tests on ranks; significant tests indicate that the observer-detection probability differs among either plants or species.

H2b: Rockfish identified as industry only and observer only in landings are the same species

As in theory industry conducts a census, there is no possibility that industry staff failed to detect a species in a landing. Therefore, observer-only identifications within a landing indicate misidentification by industry. However, identifying which species was misidentified, and the species as what it was mislabelled is problematic. Instances of rockfish misidentification between data sources were defined as the presence of industry- and observer-identified rockfish within the same delivery with nearly identical species' proportions and physical appearances, following observer reference texts. Evidence of more subtle species "switching", whereby one species may be routinely substituted for another, was examined by calculating relative difference values, i.e. the industry estimate by species less that of the observer as a proportion of the total delivery weight reported by the industry, screening for outliers, and performing Pearson's product-moment correlations on the difference values between pairs of species for deliveries that contained both species. Significant correlations provide support for *H*2b.

H2c: Rockfish are misidentified by industry to avoid fishery closures and extend the fishing season

Weekly TAC reports published by the NMFS inform industry as to how much of each species remains available for harvest. Cumulative values of D_i were generated for each day of the project and compared with the release date and quantity of weekly TAC reports (NMFS, 2011b). An acute trend in D_i coinciding with the release of a report indicating a nearly exhausted quota and imminent fishery closure would support acceptance of *H*2c.

Results

More than 9 million kilogrammes of fish were landed in 29 deliveries to five processing plants during the study in July 2004. This period accounted for most of the landings counting towards the rockfish TAC in the central Gulf of Alaska during that year (Figure 1). Each observer participated in the project for 9–11 deliveries. Species-specific patterns in total D_i were evident. Northern rockfish showed the greatest positive weight differences, and Pacific ocean perch the most negative ones (Table 1). The industry consistently estimated greater weights for demersal shelf rockfish and northern rockfish than the observers, whereas the opposite condition was found for Pacific ocean perch and pelagic shelf rockfish delivered to four of the five processing plants (Figure 2).

$H_0$1: The catch proportions of the same species are not different between sources among plants and/or species

Linear regressions revealed no evidence of systematic differences between data sources in the species-catch proportions across landings when data were aggregated within each processing plant, although there was high variance within plant E (Figure 3). When these same data were aggregated by species, however, significant differences from the expected 1:1 relationships were found. For example, the *y*-intercept was significantly above zero for Pacific ocean perch (POP), and the regression slope was significantly less than one for "other shelf rockfish" (OSR; Figure 4).

$H_0$2: Rockfish misidentification does not differ among plants and/or species

Mismatches between species identified by industry staff and observers were common. Overall, 79% and 51% of deliveries contained industry- and observer-only identifications, respectively. Yelloweye, redbanded, and rosethorn rockfish were only identified by industry, whereas redstripe and black rockfish were only identified by observers.

Neither the incidence of industry-only nor that of observer-only data was significantly different among processing plants (industry $\chi^2 = 4.27$, d.f. $= 4$, $p = 0.37$; observer $\chi^2 = 3.47$, d.f. $= 4$, $p = 0.482$). However, similar tests indicated that there was a significant difference among species in both data sources (industry $\chi^2 = 63.64$, d.f. $= 6$, $p \leq 0.001$; observer $\chi^2 = 27.9$, d.f. $= 6$, $p \leq 0.001$). The incidence of industry-only data was much less for Pacific ocean perch and much greater for demersal shelf rockfish, relative to the other species examined. In contrast, "other shelf rockfish" were more likely to be identified by observers only (Table 2).

*H*2a: Industry-only rockfish identifications resulted from small observer sampling fractions

The observer sample size averaged 81.3 kg per delivery in this study (median 80.0 kg; range 49.0–109.2 kg), whereas total

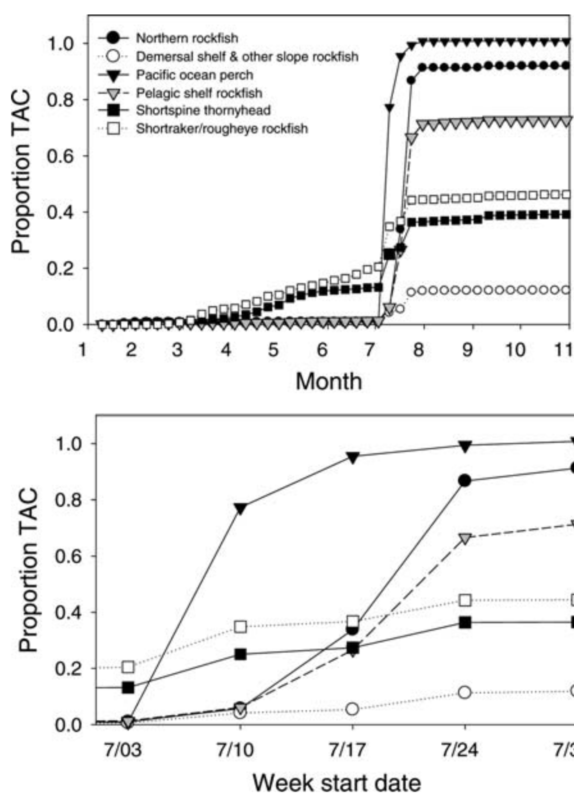

Figure 1. Catches by species for the central Gulf of Alaska as reported in the NMFS catch accounting system for 2004, expressed as a proportion of the TAC for the entire year (top) and the study period (bottom).

Table 1. Total weight (kg) of rockfish within species complexes (SCs) reported by fish tickets (industry), comparable observer estimates (observer), and their overall differences (D = industry − observer).

Common name	Latin name	SC	Industry	Observer	D	μD	s.d. D	n
Northern rockfish	*Sebastes polyspinis*	NOR	603 855	535 813	68 041	2 958	7 758	23
Yelloweye rockfish[a]	*Sebastes ruberrimus*	DSR	1 658	0	1 658	128	118	13
Shortspine thornyhead	*Sebastolobus alascanus*	SST	5 090	4 002	1 088	60	436	18
Redbanded rockfish	*Sebastes babcocki*	OSR	624	0	624	125	163	5
Shortraker rockfish[a]	*Sebastes borealis*	SRR	1 409	1 182	227	76	22	3
Rosethorn rockfish	*Sebastes helvomaculatus*	DSR	17	0	17	17	–	1
Rougheye rockfish[a]	*Sebastes aleutianus*	SRR	525	788	−263	−53	436	5
Sharpchin rockfish	*Sebastes zacentrus*	OSR	5 880	7 599	−1 719	−191	1 717	9
Redstripe rockfish	*Sebastes proriger*	OSR	0	2 903	−2 903	−968	657	3
Harlequin rockfish	*Sebastes variegates*	OSR	9 764	14 158	−4 394	−549	2 020	8
Black rockfish	*Sebastes melanops*	PSR	0	6 456	−6 456	−1 614	1 703	4
Dusky rockfish[a,b]	*Sebastes variabilis*	PSR	349 332	361 530	−12 197	−488	4 986	25
Pacific ocean perch	*Sebastes alutus*	POP	878 849	922 646	−43 796	−1 622	5 843	27

Species are ranked by decreasing difference values. The mean (μ) and standard deviation (s.d.) of difference values across deliveries, and the number of deliveries in which a species was present in at least one data source (n) are also provided. Species complexes are DSR, demersal shelf rockfish; NOR, northern rockfish; OSR, other shelf rockfish; PSR, pelagic shelf rockfish; SRR, shortraker/rougheye rockfish; and SST, shortspine thornyhead rockfish.
[a]Identified as a species that should receive the most conservation attention (Magnuson-Ford *et al*., 2009).
[b]Species considered together with *S. ciliatus* by Magnuson-Ford *et al.* (2009) in this determination.

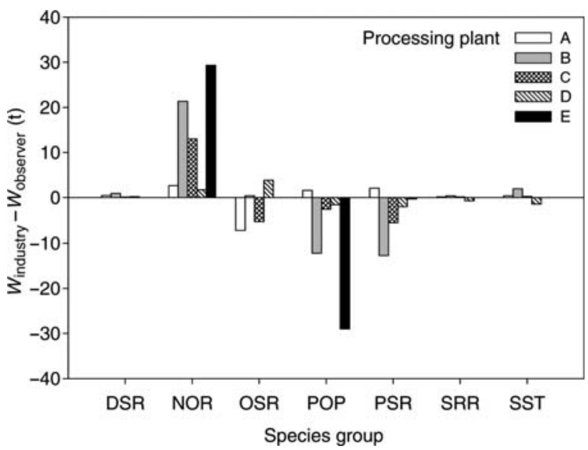

Figure 2. Difference values, i.e. industry weight (W_{industry}) minus observer expanded weight (W_{observer}) for each species-complex aggregated over the entire study for each processing plant. Species-complex definitions follow Table 1.

landed weight averaged 64.03 t (median 68.24 t; range 22.97–115.00 t). Consequently, the observer-sampling fraction was small, averaging 0.0015, or 0.15% (median 0.12%, range 0.075–0.46%). The mean P_0 for observer samples where industry-only identifications were recorded was significantly less than that when both industry and observers identified the same species ($t = -12.01$, d.f. = 96, $p \leq 0.001$). For industry-only identifications, there was no significant difference in P_0 values among plants or species. Together, these results indicate that an observer's inability to detect a particular species in an offload was the result of low sample fractions and was not skewed towards any particular plant or species.

*H*2b: Rockfish identified as industry only and observer only in landings are the same species

Matches between the proportions of different industry-identified and observer-identified species were found in four landings (Table 3). With a single exception, the species matched made up <2% of the total catch. Three significant interspecies correlations were found: dusky rockfish with northern rockfish ($p \leq 0.01$), sharpchin rockfish with Pacific ocean perch ($p \leq 0.05$), and harlequin rockfish with shortspine thornyhead ($p \leq 0.01$; Figure 5).

*H*2c: Rockfish are misidentified by industry to avoid fishery closures and extend the fishing season

In three of the four landings listed in Table 3, the species declared by the industry had less accumulated landings relative to the TAC than the species identified by the observer. The onset of D_i deviations from zero generally coincided with the release of the first weekly TAC report for other shelf rockfish (OSR), pelagic shelf rockfish (PSR), northern rockfish (NOR), and Pacific ocean perch POP; (Figure 6). Large deviations were also noticeable in the latter two species with the release of the second weekly report.

Discussion

Identification of species is central to all biological data, catch statistics, quota debiting, and hence decisions on the status and successful management of marine resources. For this reason, the American Fisheries Society has recommended that species-specific identification of rockfish be conducted to manage these fish properly (Parker *et al*., 2000), and the North Pacific Fishery Management Council (Council) has determined that "improving species identification in catches by both processors and observers for priority species within species complexes" is an immediate concern and priority for research during the years 2010–2014. The results of this project underscore these concerns. For example, nearly all the deliveries examined contained misidentifications between industry and observers, and in one-third of the comparisons, a species reported by one source was completely absent from the other.

Erroneous quota deduction attributable to species misidentifications should be reduced where species are managed as complexes, e.g. for Alaskan rockfish. However, in all the cases examined here, erroneous rockfish identification resulted in the deduction of catch from the wrong TAC. This is likely because rockfish complexes in Alaska are based on biological criteria, e.g. where caught, life history, rather than appearance. Basing species

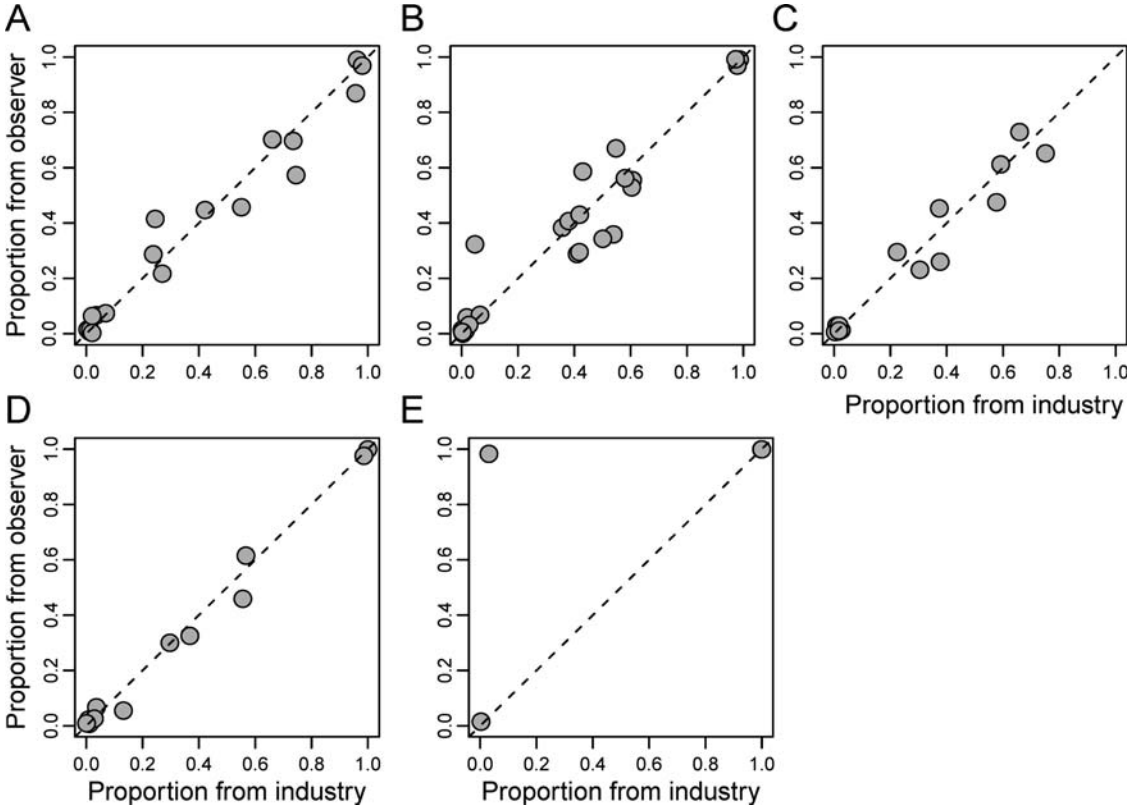

Figure 3. Relative species composition (proportion of total) in landings between industry and observer personnel for processing plants A–E. Dotted lines denote perfect agreement between data sources. Each point is one species complex for a given delivery.

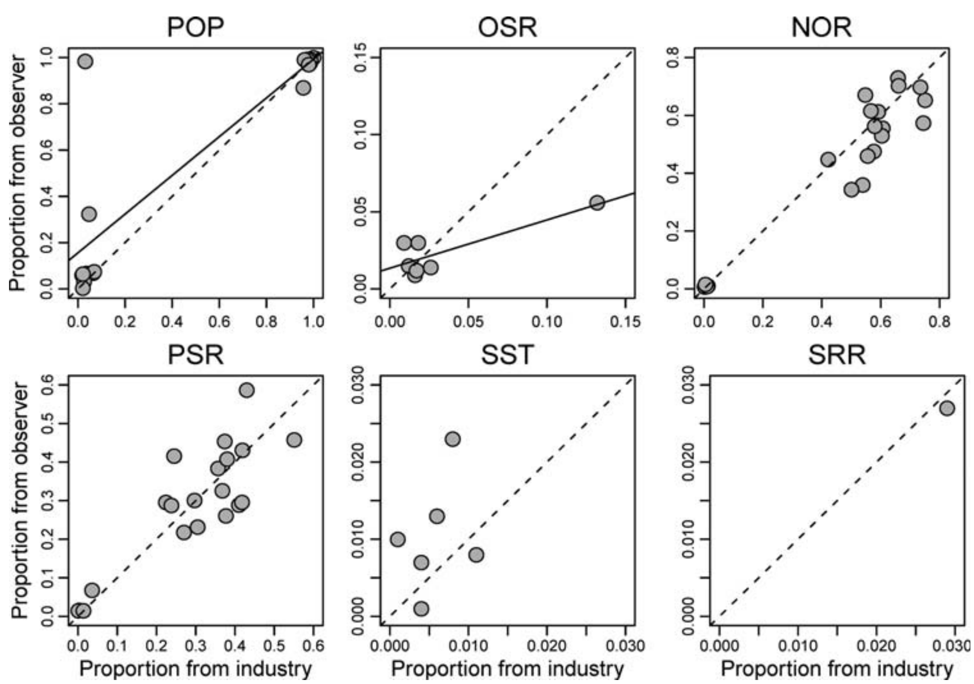

Figure 4. Relative species composition (proportion of total) in landings between industry and observer sources by species complex (see Table 1 for definitions). Dotted lines denote perfect agreement between data sources, and solid lines indicate linear regressions with intercepts or slopes that are significantly different from expected. Each point is the species complex for a given delivery.

Table 2. Incidence of industry-only (I) and observer-only (O) identifications of rockfish from 29 landings deliveries made in Kodiak, AK.

Source data	Demersal shelf rockfish	Northern rockfish	Other shelf rockfish	Pacific ocean perch	Pelagic shelf rockfish	Shortraker/ rougheye rockfish	Thornyhead rockfish
Both	0	21	7	21	20	1	6
Observer	0	0	12	5	4	1	1
Industry	14	2	6	1	5	6	11
Total	14	23	25	27	29	8	18
Proportion O	0	0	0.48	0.18	0.13	0.12	0.05
Proportion I	1.00	0.08	0.24	0.03	0.17	0.75	0.61

χ^2 equality tests of proportions performed on the last two rows were highly significant ($p \leq 0.001$). Species within each complex follow Table 1.

Table 3. Landings where the species identification (ID) by industry staff and observers differed within the same delivery, but could be matched through their similar catch proportions (shown as SCP Industry and SCP Observer, respectively), showing the total weight of the delivery (TW), the percentage difference in proportions [100 × (SCP industry − SCP observer); PDIFF], and the total difference weight between data sources (difference).

Parameter	18 July Plant E	23 July Plant C	24 July Plant C	25 July Plant A
Industry ID	*Sebastes polyspinis* (NOR)	*Sebastes zacentrus* (OSR)	*Sebastes borealis* (SRR)	*Sebastes aleutianus* (SRR)
Observer ID	*Sebastes alutus* (POP)	*Sebastes alutus* (POP)	*Sebastes alutus* (POP)	*Sebastes zacentrus* (OSR)
TW (kg)	30 355	69 155	72 947	22 970
SCP Industry	0.966	0.024	0.001	0.006
SCP Observer	0.984	0.023	0.002	0.004
PDIFF (%)	−1.8	0.1	−0.1	0.2
Difference (kg)	28 411	1 591	146	92
ITAC	0.36	0.93	0.96	0.96
OTAC	0.95	0.98	0.98	0.93

ITAC and OTAC are the proportion of the TACs in the central Gulf of Alaska for the Industry ID and Observer ID species, respectively, accounted for by the landing date. Species complexes in parenthesis follow those in Table 1.

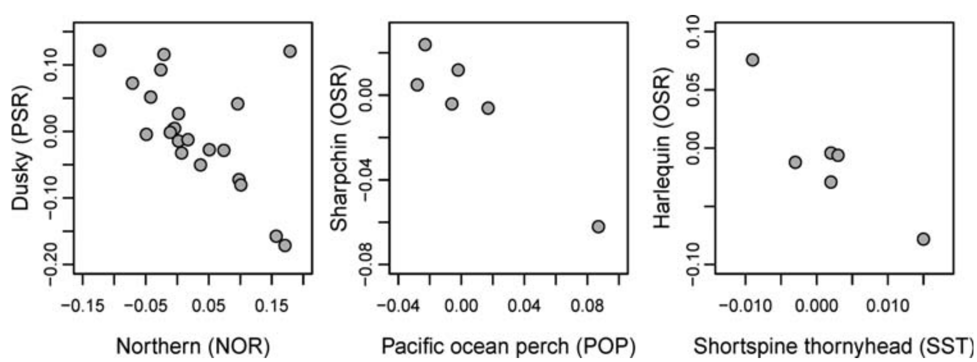

Figure 5. Correlations between observer- and industry-based landings information. The metric on both axes is the industry estimate by species less that of the observer as a proportion of the total delivery weight reported by the industry. Significant correlations in these difference values are evident when plotted for three species-pairs, where points depict individual deliveries (29 possible).

complexes on biological criteria may have ecological merit (Rooper, 2008), but it does not reduce the chance of erroneous quota deduction in fishery management. Among the species complexes managed by the NMFS, northern rockfish were misidentified as (i) dusky rockfish (a pelagic shelf rockfish) from correlation tests, and (ii) Pacific ocean perch from comparisons of relative species weights. Although the former type of misidentification indicates a need for training or education outreach, the latter deserves more attention because quota-debiting errors were nearly always in the same direction. For example, industry excesses in the total weight of northern rockfish were offset by shortages in Pacific ocean perch of similar magnitude in four of the five processing plants examined.

As northern rockfish and Pacific ocean perch represent the first and second most landed rockfish in this study, it is surprising that these species were so widely misidentified. Where TAC constraints on some species restrict the catches of others, there is a risk of misreporting by industry participants (Branch *et al.*, 2006). There is some evidence to suggest that these misidentifications were deliberately made to avoid fishery closures. For example, the day after the release of an NMFS report showing the catch for the area to be at 95% of the TAC for Pacific ocean perch, and 36% for northern rockfish, all the Pacific ocean perch (which was the main species) in one landing were misidentified as northern rockfish by industry staff. Moreover, discrepancies in the total catch weights of these two species from industry and observer sources

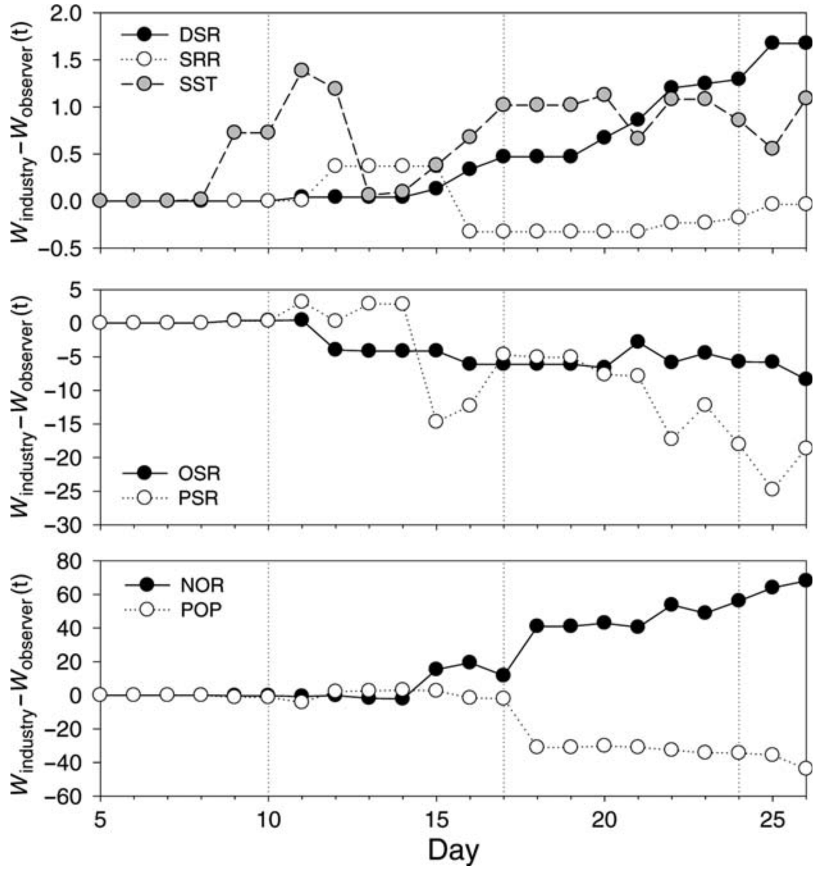

Figure 6. Difference values, i.e. industry weight ($W_{industry}$) minus observer expanded weight ($W_{observer}$) for deliveries of rockfish species (definitions as in Table 1) expressed as a running total by date in July 2004. For clarity, data are presented in three plots with different scales of total difference: <2 t (top panel), 2–20 t (middle panel), and >20 t (lower panel). Vertical dotted lines show the dates when weekly catch reports were released by the NMFS.

continued unabated after the aforementioned delivery, always in the same direction (i.e. the industry-reported weights for northern rockfish and Pacific ocean perch were, respectively, less and greater than the observer estimates). In the extreme case, if industry intentionally misidentifies species to preclude fishery closures, there is a risk of serial overfishing. In this process, once the most desirable species of rockfish approaches its TAC, its identity is switched to the next most desirable species with remaining quota, and the process is repeated. Paradoxically, not only would overfishing not be evident in the records, but all species would appear to have been managed under or at the desired harvest levels. The results of this study do not support the conclusion that the Kodiak rockfish fishery operated under the extreme misreporting scenario described above, but the possibility of some intentional misidentifications is disconcerting.

Attaining the goal of "improving species identifications" set out by the Council is difficult because the North Pacific Groundfish Observer Programme (NPGOP) operates under multiple, often conflicting objectives. For example, NPGOP observers need to obtain unbiased, statistically rigorous, and reliable estimates of fishing activities (acting as scientists) and also monitor the fishery for regulatory violations (acting as compliance monitors). Specifically, scientific sampling most often employs a random design to facilitate interchangeability between observed and unobserved units (e.g. hauls), whereas sampling for compliance monitoring is often performed under a more systematic design (Cotter and Pilling, 2007). Despite the NPGOP being among the largest and oldest programme of its kind in the United States (French *et al.*, 1982), improvements can be made. There is a clear need to verify the identity of species reported by industry in the landing reports associated with shoreside deliveries of rockfish from catcher vessels, and observers can provide such a service. In fact, observers are responsible for most of the available information on control violations in the North Pacific (Porter, 2010).

Observer sample sizes larger than those realized in this study are also desirable. The results support the notion that observers failed to identify some species because of the low detection probabilities associated with the small sampling fractions and rarity of these fish. Instructing observers to obtain 100 rockfish unnecessarily limited the sample size, and some improvement should be logistically feasible. For example, observers deployed on trawlers face more demanding work circumstances owing to a lack of space, accessibility to the unsorted catch, and safety considerations than shore-based observers who have access to conveyor belts. Nonetheless, these at-sea observers obtained sample sizes that were >3× the size of those obtained in the current study (Cahalan, 2010). Despite the small sampling fractions realized in the present study, however, the observer recorded at least one species missed by industry staff in more than half the offloads examined.

How observers collect samples in processing plants depends on whether they are working towards a scientific or compliance-monitoring objective. Under a scientific objective such as catch estimation, where not only the identity but also the total weights of landed fish are of interest, a stratified random design (with time as the unit) gives multiple uncorrelated samples of landed rockfish that would facilitate the calculation of unbiased variance estimates. Although collection of multiple large samples may not greatly change the mean observer estimate, it has been shown elsewhere to greatly reduce the variance of species-composition estimates (Conners *et al.*, 2009). Indeed, since 2008, observers within the NPGOP have employed a stratified random-sampling design to determine the species composition of unsorted fish on board Alaskan vessels that process their catch at sea (Cahalan *et al.*, 2010). An alternative way to obtain larger observer sampling fractions from landed rockfish would be to adopt a more compliance-monitoring approach to the misidentification problem. Taking advantage of the regulations that require industry staff to sort all rockfish to species level before processing at the plant, observers could monitor the sorting by plant staff and selectively sample from various sorted rockfish species to determine the veracity of industry identifications.

A framework to optimize observer-programme goals to quantify fishing activity and to monitor compliance was proposed by Furlong and Martin (2000) and modified by Benoît and Allard (2009). In this framework, observers are deployed to processing facilities for the purpose of compliance monitoring, and differences between the industry and observer data within a processing plant are used to generate a "compliance index", where each plant is compared with its peers. This index is used to weight the priority for an observer deployment to a particular plant in future years, with greater relative differences between data sources increasing the probability. The desire to avoid excessive supervision should be an incentive for industry to enforce its own compliance with respect to species identification, so a form of co-management that has been shown to be particularly successful can be realized (Gutiérrez *et al.*, 2011). The deployment of observers for compliance monitoring is augmented simultaneously with their random deployment to shoreside processing plants for scientific reasons such as the collection of otoliths, length distributions, and genetic samples (Benoît and Allard, 2009). Alternatively, where staff resources are limiting, the same observers could be deployed according to a randomized probability applied to successive landings of catcher vessels, notified through a "hail-in" system, with the purpose of their deployment (scientific or compliance monitoring) also randomized, so reducing a fisher's ability to predict when observations will take place. Although there have been attempts to weight the priorities of diverse observer programmes such as the NPGOP and therefore to "optimize" them (Miller *et al.*, 2007), such efforts are computationally cumbersome and difficult to maintain over a long period. In contrast, the hybrid observer-deployment system proposed by Benoît and Allard (2009) can reduce misidentifications in the Alaskan rockfish fishery, because it (i) includes comparisons between industry and observer data and (ii) addresses both scientific and compliance-monitoring needs.

Because of the sensitivity of rockfish to overexploitation, the fishery harvest in the central Gulf of Alaska rockfish programme is governed by a suite of regulations that include catch-share rules, gear and seasonal restrictions, and 100% observer monitoring. Yet despite these regulations, the present study has revealed catch misreporting in the form of species misidentification. For regulations governing fisher behaviour to be effective in fishery management, they must not only be logical but also enforceable (Beddington *et al.*, 2007). Reducing misidentification within fisheries exploiting complex species assemblages, such as those landing in Kodiak, will require experienced observers with excellent knowledge of species identification. As the ability of observers to discriminate between similar species in diverse fisheries improves with the development and release of new identification keys, better data should be realized over time, facilitating greater data resolution for fishery managers (Stevenson, 2004; Reuter *et al.*, 2010) and enforcement agencies to clarify misreporting practices (Randall, 2004). Moreover, limited-access programmes often incur additional costs for data collection and compliance monitoring, so the effective and efficient deployment of observers towards both of these tasks, through the methods described above, should help to reduce the costs of such activities (NOAA, 2011). The use of observers to verify species identifications should sustain and substantiate the positive reviews that Alaskan groundfish management has received in global assessments (e.g. Worm *et al.*, 2009). As this small-scale study has demonstrated, one of the key assumptions made by fishery managers worldwide that the identities of species recorded on forms are correct and without error may be incorrect.

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References

AFSC. 2010. Observer Sampling Manual. Fisheries Monitoring and Analysis Division, North Pacific Groundfish Observer Program, Alaska Fisheries Science Center, Seattle. 571 pp. http://www.afsc.noaa.gov/FMA/Manual_pages/MANUAL_pdfs/manual2010.pdf (last accessed 21 July 2010).

Beddington, J. R., Agnew, D. J., and Clark, C. W. 2007. Current problems in the management of marine fisheries. Science, 316: 1713–1716.

Benoît, H. P., and Allard, J. 2009. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Canadian Journal of Fisheries and Aquatic Sciences, 66: 2025–2039.

Bracken, B. 1986. The history of the rockfish fisheries in Alaskan waters. Proceedings of the International Rockfish Symposium. University of Alaska, Sea Grant Report, 87-2. 8 pp.

Branch, T. A., Hilborn, R., Haynie, A. C., Fay, G., Flynn, L., Griffiths, J., Marshall, K. N., *et al.* 2006. Fleet dynamics and fishermen behavior: lessons for fisheries managers. Canadian Journal of Fisheries and Aquatic Sciences, 63: 1647–1668.

Cahalan, J. 2010. At-sea monitoring of commercial North Pacific groundfish catches: a range of observer sampling challenges. Alaska Fishery Science Center Quarterly Report, July–September 2010. http://www.afsc.noaa.gov/Quarterly/jas2010/jas10featurelead.htm (last accessed 02 February 2011).

Cahalan, J., Mondragon, J., and Gasper, J. 2010. Catch sampling and estimation in the federal groundfish fisheries off Alaska. NOAA Technical Memorandum, NMFS-AFSC-205. 51 pp.

Conners, M. E., Cahalan, J., Gaichas, S., Karp, W. A., Loomis, T., and Watson, J. 2009. Sampling for estimation of catch composition in Bering Sea trawl fisheries. NOAA Technical Memorandum, NMFS-AFSC-199. 77 pp.

Cotter, A. J. R., and Pilling, G. M. 2007. Landings, logbooks and observer surveys: improving the protocols for sampling commercial fisheries. Fish and Fisheries, 8: 123–152.

French, R., Nelson, R., and Wall, J. 1982. Role of the United States observer program in management of foreign fisheries in the Northeast Pacific Ocean and eastern Bering Sea. North American Journal of Fisheries Management, 2: 122–131.

Furlong, W. J., and Martin, P. M. 2000. Observer deployment in the fishery and regulatory self-enforcement. Proceedings of the 10th Biennial Conference of the International Institute of Fisheries and Trade, Corvallis, OR. 9 pp.

Gutiérrez, N. L., Hilborn, R., and Defeo, O. 2011. Leadership, social capital and incentives promote successful fisheries. Nature, 470: 386–389.

Jacquet, J. L., and Pauly, D. 2008. Trade secrets: renaming and mislabeling of seafood. Marine Policy, 32: 309–318.

Magnuson-Ford, K., Ingram, T., Redding, D. W., and Mooers, A. Ø. 2009. Rockfish (*Sebastes*) that are evolutionarily isolated are also large, morphologically distinctive and vulnerable to overfishing. Conservation Biology, 142: 1787–1796.

Miller, T. J., Skalski, J. R., and Ianelli, J. 2007. Optimizing a stratified sampling design when faced with multiple objectives. ICES Journal of Marine Science, 64: 97–109.

NMFS. 2011a. Central Gulf of Alaska (GOA) Rockfish Program. http://www.fakr.noaa.gov/sustainablefisheries/goarat/default.htm (last accessed 20 November 2011).

NMFS. 2011b. Archived catch reports, Central Gulf, North Pacific Fisheries Management Council Statistical Area 620. http://www.fakr.noaa.gov/2004/2004.htm (last accessed 31 January 2011).

NOAA. 2009. Fisheries of the United States. Annual Report by the Fisheries Statistics Division, Current Fishery Statistics No. 2008. National Oceanic and Atmospheric Administration, Silver Spring, MD. 103 pp.

NOAA. 2011. Draft NOAA Catch share policy. http://www.nmfs.noaa.gov/sfa/domes_fish/catchshare/docs/draft_noaa_cs_policy.pdf (last accessed 31 January 2011).

Orr, J. W., and Blackburn, J. E. 2004. The dusky rockfishes (Teleostei: Scorpaeniformes) of the North Pacific Ocean: resurrection of *Sebastes variabilis* (Pallas, 1814) and a redescription of *Sebastes ciliatus* (Tilesius, 1813). Fishery Bulletin US, 102: 328–348.

Orr, J. W., Brown, M. A., and Baker, D. C. 2000. Field guide to the rockfishes (Scorpaenidae) of Alaska. NOAA Technical Memorandum, NMFS-AFSC-117. 47 pp.

Orr, J. W., and Hawkins, S. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fishery Bulletin US, 106: 111–134.

Parker, S. J., Berkeley, S. A., Golden, J. T., Gunderson, D. R., Heifetz, J., Hixon, M. A., Larson, R., *et al.* 2000. Management of Pacific rockfish. Fisheries, 25: 22–29.

Porter, R. D. 2010. Fisheries observers as enforcement assets: lessons from the North Pacific. Marine Policy, 34: 583–589.

R Development Core Team. 2010. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Randall, J. K. 2004. Improving compliance in U.S. Federal fisheries; an enforcement agency perspective. Ocean Development and International Law, 35: 287–317.

Reuter, R. F., Conners, M. E., Dicosimo, J., Gaichas, S., Ormseth, O., and Tenbrink, T. T. 2010. Managing non-target, data-poor species using catch limits: lessons from the Alaskan groundfish fishery. Fisheries Management and Ecology, 17: 323–335.

Rooper, C. N. 2008. An ecological analysis of rockfish (*Sebastes* spp.) assemblages in the North Pacific Ocean along broad-scale environmental gradients. Fishery Bulletin US, 106: 1–11.

Stevenson, D. E. 2004. Identification of skates, sculpins, and smelts by observers in the North Pacific Groundfish Fisheries (2002–2003). NOAA Technical Memorandum, NMFS-AFSC-142. 67 pp.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., *et al.* 2009. Rebuilding global fisheries. Science, 325: 578–585.