Aleuts, Sea Otters, and Alternate Stable-State Communities

Charles A. Simenstad, James A. Estes, Karl W. Kenyon

Interpretations of paleoecological evidence in the Aleutian Islands have been made with the assumption that aboriginal Aleuts exploited and maintained a stable and uniform resource base (1, 2). Laughlin (2) supposed the ecological role of aboriginal Aleuts to be “a moderating influence on population fluctuations in the other resident species” such as sea otters (Enhydra lutris) and their principal prey. These interpretations presume that aboriginal man arrived in the New World as a “prudent predator” (3) and survived as a wise manager of the natural resources he exploited. These interpretations also are consistent with the popular hypothesis that paleoecological changes, such as Pleistocene extinctions of New World megafauna, were caused directly by rapid environmental change—climatic and geological phenomena producing high rates of extinction and speciation. There are, however, alternative hypotheses, such as that proposed by Martin and Wright (4), postulating that aboriginal man reduced or eliminated various large vertebrates upon arriving in the New World. Results of recent ecological and archeological investigations in the Aleutian Islands have prompted us to consider the Martin-Wright hypothesis specifically for aboriginal Aleuts.

Predation is important to the structure and organization of many natural communities (5). The “keystone predator’s” role (6) of sea otters is particularly dramatic in that two alternate nearshore community structures are maintained by the presence or absence of sea otters in the Aleutian Islands (7), supporting Sutherland’s (8) evidence that multiple stable-state communities can occur in one environment. Our intent here is to integrate this understanding of sea otter-induced alternate communities with a reinterpretation of the faunal remains in Aleut middens to propose that (i) multiple stable-state communities can be found historically and presently in the Aleutian Archipelago and that (ii) aboriginal man, the Aleut in this case, was instrumental in driving the community from one stable state to another (Fig. 1). To our knowledge this article is the first reinterpretation of the faunal remains in Aleutian middens to propose that (i) multiple stable-state communities can be found historically and presently in the Aleutian Archipelago and that (ii) aboriginal man, the Aleut in this case, was instrumental in driving the community from one stable state to another (Fig. 1).

Alternate Communities

Through intense predation, the sea otter profoundly influences the organization of nearshore communities in the North Pacific Ocean (7, 9, 10). We have identified some of the more visible consequences of sea otter predation by comparing islands in the western Aleutian Archipelago with and without sea otters (7, 11–13). Differences between these two insular communities (Table 1) are dramatic even to the casual observer. Dense sea otter populations reduce herbivorous benthic macroinvertebrates such as sea urchins (Stronglyocentrotus polycanthus) (14), limpets (Collisella pelta), and chitons (Katharina tunicata, Cryptochiton stelleri) to sparse populations of small individuals. This interaction in turn allows an abundant association of macroalgae to flourish on the rocky substrate of the broad littoral benches and shallow (0 to 20 meters) sublittoral zones (7, 10). In contrast, islands with few or no sea otters support dense populations of large herbivorous invertebrates which, by overgazing, virtually exclude the association of fleshy macroalgae. These islands are characterized by bare rocky substrates covered by a dense carpet of sea urchins and, in some areas, abundant bivalves (Modiolus rectus), colonial tube worms (Polamilla reniformis), predaceous asteroids (Leptasterias alaskensis, Cossaster papposus, Solaster simpsoni and a number of species yet to be identified), epibenthic macrocrustaceans (Telmessus cheiragonus, Erimacrus isenbecki, and Elassochirus tenuimanus), and octopus (Octopus dofleini) (15).

The association of macroalgae is the major source of marine primary production in the western Aleutian Islands and other north temperate areas (16). Consequently, islands lacking sea otters and thus the robust association of macroalgae apparently are relatively unproductive compared with islands where sea otters are abundant (7, 17). This condition is further manifested both directly and indirectly in the composition and standing crop of nearshore fishes. Islands dominated by sea otters characteristically have high standing crops of species that depend on and use sublittoral macroalgae for protection and spawning substrate. A characteristic detritus-based food web supports most of these fishes through abundant populations of epibenthic crustaceans—mysids and amphipods—which are sustained by breakdown of macroalgae (18, 19). In contrast, islands without otters possess noticeably fewer nearshore fishes, and those present typically are species associated with the pelagic ecosystem and its food web. This condition apparently has more far-reaching effects on higher trophic forms, because islands without sea otters have a comparatively depauperate vertebrate fauna in terms of both number of species and abundance of individuals (7).
Since cessation of large-scale fur hunting in 1911, the sea otter has reestablished its Aleutian populations throughout most of the archipelago, and in these regions, the nearshore community is characterized by sparse populations of sea urchins and abundant beds of macroalgae. Aboriginal Aleuts arrived in the western Aleutian Islands about 2500 years ago, although today they are extinct in that area.

The Aleut

Faunal remains in Aleut and pre-Aleut kitchen middens excavated in the Aleutians probably are the best indication of nearshore community structure during prehistoric times (20-24). But Dall (20) and his successors have generally interpreted stratified faunal midden remains as different cultural periods, implying exploitation of a single stable community in which diverse marine mammals, macroinvertebrates, and fishes were equally available for harvest. This interpretation no doubt comes from investigations showing that the Aleuts in the eastern Aleutians depended more on seasonally abundant migratory food resources than their neighbors did in the western Aleutians (24). Even these excavations, however, indicate disruption of the more stationary component of the eastern Aleuts' food resources by overuse.

The homogeneous composition and stratified position of prominent faunal components (Fig. 2) have suggested to us another possibility, namely, that one or more shifts in the food subsistence base for aboriginal populations occurred during Aleut occupation before intrusion of Western man. We have used the previous data and have reexamined faunal material from a prehistoric Aleut midden (49 Rat 31) (25) that was excavated on the Pacific coast of Amchitka Island in 1969 (23). The strata and their major faunal components are described in Fig. 3 (26). These faunal data include the minimum number of sea otters and harbor seals (Phoca vitulina) (27) and the gram dry weights of fish bones, sea urchin spines and tests, and limpet shells per centimeter of deposition. Minor components such as mussel and chiton shell, and bones of northern fur seals (Callorhinus ursinus) and Steller's sea lions (Eumetopias jubatus) (28), are not numerous enough to include graphically. Although the faunal remains are graphed by stratum, these strata are not discrete, equal time periods but are the archeologists' designations of layers dominated by remains of certain organisms—for example, stratum E is the lens of sea urchin spines and tests seen in Fig. 2. The scale is a measurement of depth from the surface. Carbon dates at several depths indicate a uniform rate of deposition (about 1 centimeter per 10 years), and

![Generalized food web in the western Aleutian Islands emphasizing the effect of aboriginal Aleuts on the principal components of the nearshore community.](image-url)
and size with depth greatest individual size at sub-

malma), and the smooth lump sucker (Aptocyclus ventricosus), which we know to have been harvested commonly throughout the Aleuts (20, 24, 29). These fish bones and macrocrustacean exoskeletons apparently were too fragile or not calcified enough to be preserved. Soft-bodied mollusks such as cephalopods are not represented in the faunal remains for a similar reason. We further assume that the Aleut harvested food in proportion to availability, so that major shifts in harvesting strategies were imposed by changes in the availability of harvestable organisms. Correspondingly, we assume that the remains of different food organisms were not discarded in different areas, and that faunal remains in the vertical profiles through the middens represent changes in the composition of food exploited by the Aleuts through time (30).

The data in Fig. 3 indicate a strong negative relationship between the harvest of sea otters, fish, and harbor seals, on the one hand, and the harvest of sea urchins and limpets on the other. We interpret this as evidence that (i) the availability of prey items preferred by Aleuts changed greatly during the time Aleuts occupied Amchitka and (ii) this change was caused largely by Aleuts over-harvesting or harassing sea otters, with the consequence that during at least the past 2500 years the nearshore community at Amchitka shifted between one dominated by sea otters and an abundance of large invertebrate herbivores. That the Aleut was technically capable of locally reducing or eliminating sea otters during prehistoric times is supported by near elimination of sea otters from the North Pacific Ocean after the enslavement of Aleut hunters by Russian fur traders (31, 32).

The effect of Aleut exploitation was therefore twofold: (i) By overexploiting sea otters, Aleuts limited the availability of this prey, forcing a change in harvesting strategy to increasingly more available organisms such as sea urchins and limpets; and (ii) in limiting the sea otter, Aleuts induced a shift in the nearshore community toward an alternate structure as populations of invertebrates that were once limited by sea otters expanded with the sea otter's decline. Many of the sea otter's principal prey are herbivores, and these populations probably grew because of an abundance of algae and the release from intense predation. These herbivores invaded the sublittoral fringe and littoral zones where they became available for harvest by Aleuts. Eventually an alternate state of community organization was attained.

**Sea Urchin Size Frequencies**

Stratigraphic variation in the abundance of middens reveals three food exploited by the Aleuts through time (30).

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### Table 1. Comparative status of nearshore communities in Rat Islands and Near Islands, western Aleutian Islands, Alaska.

<table>
<thead>
<tr>
<th>Species (sources)</th>
<th>Rat Islands (Amchitka Island)</th>
<th>Near Islands (Shemya and Attu islands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea otters (31, 49)</td>
<td>Abundant for at least last several decades; current estimated population greater than 6000</td>
<td>Sparse; first sighting in late 1960's after extermination by fur traders; current population on Attu about 350; none at Shemya</td>
</tr>
<tr>
<td>Macrolgae (7, 10)</td>
<td>Abundant: diverse epibenthic canopy (principally four species of Laminaria, Agarum cribrosum, Rhodophyta spp.) and a dense surface canopy (Alaria fistulosa); competitive interactions predominate</td>
<td>Rare; restricted to a few species isolated in sublittoral fringe and sublittoral patches</td>
</tr>
<tr>
<td>Sea urchins, S. polyacanthus (7)</td>
<td>Rare; maximum test diameter &lt; 32 mm; increasing density and size with depth</td>
<td>Dense; maximum test diameter &gt; 100 mm; highest density and greatest individual size at sublittoral fringe</td>
</tr>
<tr>
<td>Limpets (11, C. pelta (50)</td>
<td>Density 8 m² and maximum length 51 mm</td>
<td>Density 82 to 356 m² and maximum length 67 mm</td>
</tr>
<tr>
<td>Chitons, K. tunicata, C. stelleri (7)</td>
<td>Rare; density &lt; 1 m²</td>
<td>Common; density 32 m²</td>
</tr>
<tr>
<td>Mussels, Mytilus edulis, Modiolus sp. (7)</td>
<td>Rare and small; density 3.8 m²</td>
<td>Common and large; density 722 m²</td>
</tr>
<tr>
<td>Barnacles, Balanus glandula, B. cariosus (7)</td>
<td>Rare and small; density 4.9 m²</td>
<td>Common and large; density 1215 m², dominating upper littoral zone</td>
</tr>
<tr>
<td>Nearshore fish (38, 31)</td>
<td>Abundant, diverse fauna; high standing crop supported by algae detritus-based food web</td>
<td>Sparse fauna outside littoral zone except for deepwater demersal and neritic forms and populations associated with sparse, isolated patches of macroalgae</td>
</tr>
<tr>
<td>Harbor seal, P. vitulina (52)</td>
<td>Estimated density, 8.1 per kilometer of coastline; frequently observed in groups larger than 50 animals</td>
<td>Estimated density 1.5 to 2.1 per kilometer of coastline; seldom observed in groups larger than ten animals</td>
</tr>
</tbody>
</table>

28 APRIL 1978
Fig. 2. Stratigraphic profile (front face of excavation units) of midden site 49 Rat 31, Amchitka Island. □, 14C sample locations. The figure (with minor relabeling) and the following legend are reproduced from Desautels et al. (21, figure 15): A, Dark brown highly organic humus (root zone), mixed with sand and overriding a thin lens of dark clay. B, Dark brown-colored midden and sea urchin mixture with a low and sporadic content of sand and black clay. C, Light brown sea urchin and midden mixture with light-colored sea urchin lenses and sand. D, Dark brown sea urchin and midden mixture with a high concentration of intermixed sand and clay; constitutes a basement layer of C. E, Light yellowish-white colored sea urchin and limpet mixture. F, Pure fish bone. G, Dark brown sea urchin, sand, and midden mixture. K, Light brown sea urchin and midden mixture with deposits of pure sea urchin; becomes discolored and in spots more compact towards the base of the stratum. H, Dark black greasy, highly organic, with a high concentration of fish bone. I, Dark brown sea urchin and midden mixture with an increased amount of sand; contains thin intermixed lenses of (i) black organic materials and (ii) light sea urchin lenses. J, Pure brown sand; scattered fish and mammal bone. M, Yellowish-brown sand; oxide layer appearing at base. S, Indicates sterile; starting with a pure clay lens and continuing down into a light brownish-gray sand layer.

only species of sea urchin known to have inhabited the western Aleutians during the Recent epoch. Therefore we suspected that some parts of Aristotle’s Lantern in the midden remains might indicate the size of Aleut-harvested urchins. The demipyramids, which are the thickest and most robust parts of Aristotle’s Lantern, were chosen as the most likely indicator, since they are not prone to wear and regeneration from grazing.

The correlation between sea urchin diameter and demipyramid length was determined from living specimens collected at Amchitka and Shemya Islands (Table 2). We found that linear regressions of test diameter and demipyramid length were not significantly different between Amchitka and Shemya ($F_{4,29} = 3.61, P > .05$), and that the common regression function

$$y_i = -5.9484 + 5.1732x_i$$

where $y_i$ equals test diameter and $x_i$ equals demipyramid length, was extremely precise ($r = .9838$).

The high correlation between urchin diameter and demipyramid length has allowed us to estimate accurately and precisely the size of sea urchins harvested by Aleuts at Amchitka. Figure 4 illustrates size frequency histograms by stratum for sea urchins deposited in the Amchitka midden, together with comparable data from recent collections from the littoral and shallow sublittoral zones at Amchitka (12) and Attu Islands (15). These data demonstrate that the size-frequency distributions of sea urchins gathered by Aleuts occupying the midden were virtually constant throughout the period of Aleut occupancy. Only “M stratum,” representing the earliest period of occupation of this site, provides no record of sea urchins. Most important, these size-frequency distributions typify present-day communities devoid of sea otters, as shown by the data from Casco Point [see also (7)] which is outside the range of the small population of sea otters now occupying that island (33). In contrast, these distributions contain larger sea urchins than we found either at Pisa Point (34), which now is in the center of the sea otters’ range on Attu, or at Amchitka where sea otters are currently abundant (35). Furthermore, whereas sea otters have been abundant at Amchitka for at least several decades, in contrast with the small, recently established population at Attu, the size-frequency distributions of sea urchins at Pisa Point on Attu and those from Amchitka are nearly identical. From these observations and data we conclude that even a sea otter population at low den-
sity rather quickly causes a noticeable shift in the size-frequency distribution of sea urchins toward smaller individuals.

The reconstructed size-class distributions of sea urchins (Fig. 4) therefore imply that a community lacking or nearly devoid of sea otters persisted (at least locally) throughout the time Aleuts occupied Amchitka. Aleuts probably selectively gathered the largest urchins available to them, and although such selective behavior would tend to mask minor changes in the size-frequency distribution of sea urchins over time, it could not account for the distributions observed in the midden strata if many sea otters were present (36).

The most reasonable interpretation of midden faunal remains is that there was some spatial disparity in Aleut hunting and gathering activities. We suggest that Aleuts gathered sea urchins and limpets near the villages—areas from which sea otters were harvested or harassed to near extinction. Later hunting (and perhaps fishing) activity was apparently directed toward more distant areas, perhaps even other islands. This explanation is most plausible because even sparse populations of sea otters cannot occur in the same place as sea urchins of the size gathered by Aleuts (37).

The Fish Assemblages

Abundance of fish in the various midden strata is correlated with the abundance of sea otters (Fig. 3). This pattern follows logically from our recent findings that the abundance of nearshore fishes is positively correlated with the abundance of macroalgae, and therefore with a high-density population of sea otters (38). However, although the relationship between aboriginal Aleuts, sea otters, and certain herbivorous macroinvertebrates seems fairly clear, the interpretation of coincident availability and harvest of specific nearshore fishes is more complicated. The relative abundance of principal fish species occurring in the midden strata is illustrated in Fig. 5. These data were derived from estimates of the minimum numbers of fish, based on the abundance of characteristic head bones (39).

Information concerning Amchitka's recent fish communities (18) suggests that the marine fish assemblage available to the Aleuts included two components, only one of which was directly tied to the structure of the nearshore community. One component includes species probably little affected by Aleut fishing pressure or by kelp abundance, such as offshore (> 40 m depth) demersal or epi-benthic fishes, and several seasonal or transient inhabitants of nearshore communities such as Atka mackerel (Pleurogrammos monopterygius), Pacific halibut (Hippoglossus stenolepis), and rock sole (Lepidopsetta bilineata). These species are not directly dependent on nearshore communities for food or protection, although they may use these waters periodically for spawning and, as with the rock sole, their juveniles may occupy the nearshore community as a nursery area. In the eastern Aleutians, where these fishes are generally more abundant, they constituted more significant food resources and contributed to seasonal patterns in resource exploitation by the Aleuts of that region (24).

The second component of the fish fauna includes species that are more permanent members of the nearshore fish assemblage, including rock greenling...
(Hexagrammos lagocephalus), red Irish lord (Hemilepidotus hemilepidotus), rockfish (Sebastes spp.) (40), great sculpin (Myoxocephalus polyacanthocephalus), and smooth lump sucker (A. ventricosus). Pacific cod (Gadus macrocephalus) represents a transitional species which, although also found in deeper waters offshore, occupies the nearshore waters during much of the year. These species characterize the otter-dominated community at Amchitka, or once did (18, 31). By their reliance directly on the kelp community for protection and spawning substrate, or indirectly on the detritus-based food web, they represent populations which (i) could have been overexploited and (ii) should have been reduced with expansion of the sea urchin population and declining kelp abundance.

Apparently the Aleut, by controlling the abundance of sea otters, indirectly influenced the concurrent abundance (Fig. 3) of these fishes. Data from the midden strata (Fig. 5), in conjunction with our recent collections at Amchitka and Attu, support this conclusion. Fishes of the exposed, rocky nearshore habitat were more abundant at Amchitka than at Attu (as much as 44 times the catch per unit effort), although percentage composition of species was not strikingly dissimilar. Rock greenling predominated in both communities and, when the small patches of kelp bed habitat persisting at Attu were sampled, catch per unit effort for this species was similar to that of Amchitka. Thus we believe that the availability of nearshore fishes is strongly correlated with the abundance of macroalgae.

Nearshore fish species (rock greenling, red Irish lord, and Pacific cod) typically were exploited more successfully than offshore species (Fig. 5). While the abundance of both components is correlated with patterns of sea otter/urchin abundance (Fig. 3), the nearshore component consistently predominates throughout all strata. This suggests that Aleut fishing was directed principally at nearshore areas and that offshore species were probably caught incidentally to the nearshore component. The predominance of nearshore fish remains in the midden also supports the argument that fluctuations in fish abundance (Figs. 3 and 5) were an effect of overexploitation of sea otters by Aleuts and the consequences to the nearshore community.

Harbor Seals

The distribution of harbor seal bones through the midden strata suggests a pattern of availability and exploitation similar to that of the sea otter (Fig. 3). Harbor seals may have been harvested opportunistically during periods when Aleuts hunted marine mammals. If marine mammal hunting was more intense during those prehistoric periods when sea otters were abundant, then the observed pattern of use of harbor seals would be expected, even if the abundance of seals remained nearly constant. Harbor seals probably are closely linked with the nearshore detritus-based food web.
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ciently persistent through time and space
so that there can be little doubt they are
locally stable in this context.
The question thus becomes, Why is a
particular stable state observed at a par-
ticular point in time and space? Suther-
land (8) argued that the explanation often
is found through examination of specific
historical events and the consequent un-
derstanding of how these events may
have led to the presence or absence of
key consumers in the community. His-
tory in this instance has provided us in-
sight into the relationship between the
arrival of aboriginal man to the Aleutian
Islands and the initiation of shifts in the
structure of the nearshore marine com-
munity to alternate stable states. The
mechanism for this change is the removal
of a keystone predator, which, by defini-
tion, preferentially feeds on prey that
are capable of excluding subordinate
species through competition for a requi-
site resource such as food or space. The
sea otter is clearly such a predator: its
foraging activities prevent sea urchins
from dominating food and space re-

Discussion

Natural communities can exist at mul-
tiple stable points in space or time (8)—a
stable point being characterized by a
specific structural and functional assem-
blage of species in a community which is
persistent through time and recognizably
different from other assemblages that
can occur in the same space. This defini-
tion charges us to examine communities
and to interpret community changes with
appropriate reference to time and space.
Because several important predatory
species in the western Aleutian Islands
are highly motile (for example, Aleuts
and sea otters), the appropriate space
may be as large as islands or island
groups. The appropriate time may be
decades or centuries, considering the life
histories of the communities’ “founda-
tion species” (42) such as Aleuts, sea ot-
ters, sea urchins, and various perennial
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The community probably evolved to-
ward a relatively stable state in the sense
that it apparently was resilient to minor
perturbations and that it did not undergo
major oscillations through time. We base
this conclusion on the high longevity of
many of the foundation species in the
present-day community, together with the
observation that populations of these
species are not known to fluctuate great-
ly under natural circumstances. Select-
tive forces controlling the evolution of
these patterns apparently were centered
on the control of herbivores by sea otters
and the consequent development of a
macroalgal association that served as a
keystone resource to many other species
of animals in the community.

As Dayton (10) pointed out, such hy-
pothetical speculation concerning evolu-
tionary adaptation is frequently com-
plicated by unknown interactions in-
volving recently extinct species—in this
case Steller’s sea cow (Hydrodamalis
gigas). Sea cows are known to have in-
habited Amchitka Island until the

Conclusion

Contrary to popular opinion, it is
likely that aboriginal man directly caused
the extinction of certain New World
megafauna during the Pleistocene (4). Evi-
dence for this conclusion generally has
been in the form of temporal-spatial
correlations between the extinction of
species and arrival of aboriginal man. In
this article we have employed a some-
what different approach by treating ab-
original Aleuts as key predators and as-
suming that, as such, their activities are
revealed by characteristic biotic assem-
blages that can be interpreted in the light
of a contemporary understanding of
community dynamics.

The ecological interaction critical to
our interpretation of the activities of
aboriginal Aleuts is that dense popu-
lations of sea otters in the western Aleu-
tian Islands limit sea urchins to sparse
populations of small individuals. In turn,
this interaction is important to the main-
tenance of robust kelp beds and a rich
associated fauna of fish, birds, and marine mammals. Midden remains suggest that foragers also locally disturbed their system by overexploiting the sea otter, thus minimizing or eliminating its keystone maintenance role in the community. Consistent with predictions based on observations of communities with and without sea otters, the abundance of sea otter bones through the midden strata is directly related to the abundance of marine fish and seals, and inversely related to the abundance of sea urchins and limpets.

Specific life history adaptations and interactions among species in this community probably evolved, to a large extent, either directly or indirectly in response to the disturbance role of sea otters. This role probably was constant and persistent over relatively long time periods because sea otter populations probably were seldom, if ever, subjected to disruptive disturbances from predation or climatic-geological catastrophes. For these reasons we conclude that the nearshore community had little inertia against predation of sea otters by aboriginal Aleuts. Changes in the community that followed this disturbance consequently were for the most part dramatic and not preadapted for.

References and Notes


14. Identified in earlier investigations as S. droebachiensis but recently changed to S. pycnacanthus by D. L. Pawson, Smithsonian Institution.


17. Although the systematic relationships of macroherbivores (particularly urchins) are presently unknown in this region, sizes of sea otters are characterized by high biomass and low productivity. Preliminary results of our ongoing study at Attu suggest that certain populations maintain themselves (1) by congregating near the sublittoral fringe, where plentiful algae and detritus washed from the robust algae assemblage of the littoral zones; (2) by fasting or consuming food in advance of the availability of algae, a situation in which they would still be considered as abundant. Evidence suggests that increase of the midden strata that are seen in Fig. 3, and D. F. G. T. Johnson, Jr. E. Holmes, Holmes and Narver Rep. HN-20-1045 (Las Vegas, Nev., 1972).


serve to determine which explanation is true.

40. There are presently eight species of rockfish (Sebastes spp. and Sebastolobus spp.) which have been reported from the Aleutian Islands, only two of which (Sebastes ciliatus Tiesius and S. polynus) are abundant nearshore. Sebastes ciliatus, by its prevalence and higher abundance in today's communities (15), is probably the species occurring in the midden remains.


46. L. Stejneger, Am. Nat. 21, 12 (1887).


48. Nearshore community structure at Adak Island in the Andreanof Islands is similar to that in Amchik Island in many respects (43). Sea otters are near carrying capacity at Adak (K. B. Schneider, personal communication).


50. The black oyster catcher (Haematopus bachmani), which also preys on limpets, is common in the Rat Islands but absent from the Near Islands. The presence of oyster catchers in the Rat Islands complements the effect of sea otter predation on limpets to some unknown extent.

51. C. A. Simenstad, unpublished data.


53. We thank R. Desautels for access to unpublished data and specimen material from 49 Rat 31; E. J. Dixon and the University of Alaska museum for providing additional material from 49 Rat 31; and R. Burger, P. Dayton, D. Egers, C. Fowler, C. Harris, P. Messenger, R. Enders, R. Paine, J. Palmisano, and C. E. Ray for criticizing earlier drafts of the manuscript. J. McManus and S. Nancee Steinfeldt assisted with laboratory analysis. The Aleutian Islands National Wildlife Refuge, and particularly the R. V. Aleutian Tern, provided essential logistic support on Atto during the 1976 field season. This work was supported as a research project of the National Fish and Wildlife Laboratory and by U.S. Fish and Wildlife Service contract 14-16-O008-2043, to the University of Washington, Contribution No. 482, College of Fisheries, University of Washington, Seattle 98195.

**NEWS AND COMMENT**

**Gulilemin and Schally: The Three-Lap Race to Stockholm**

The discovery made by Gulilemin's team on the eve of the January 1969 conference in Tucson was a small step forward in one sense, a major advance in another. After processing some 270,000 sheep hypothalami they had obtained a 1-milligram sample of thyrotropin-releasing factor (TRF), the hormone with which the brain directs the pituitary's control of the thyroid gland. Their sample was pure enough to allow two conclusions to be drawn. First, the sheep TRF molecule consisted of three amino acids, glutamate, histidine, and proline—the same trio that Scially had found in 1966 in his preparation of pig TRF.

Schally had been excited, at the pharmaceutical house of Merck Sharp & Dohme synthesis the six possible combinations in which the three amino acids could be arranged. (He declined to share the samples with Guillemin on the grounds, says Guillemin, that "the FDA did not allow such transfers across state lines.") But all six tripeptides were biologically inert. Scially had therefore concluded that the biologically active part of the hormone must reside in the other two thirds of the molecule, with which he could make no headway.

The second conclusion which Guillemin was able to draw was that the other two thirds didn't exist—it was just an impurity, the three amino acids being essentially the whole of the molecule.

But now came a hard decision. The three amino acids were evidently not joined together in any simple way or Schally would have solved the structure of any one of his synthetic tripeptides in 1966. If the new composition was announced at the Tucson conference, the prize of deciphering the structure would be up for grabs by any chemist in the world, with the Guillemin team having only a 3-week start.

**A Photo Finish Race for TRF**

Gulilemin took the gamble and announced the composition. In the event, his start was more than abolished. Schally, who had temporarily abandoned the TRF problem, instantly perceived how close his rival was to the coup of being first with a chemical structure for a brain hormone. At the conference site he joined forces with an eminent structural chemist, Karl Fokrers of the University of Texas at Austin, and arranged for the synthetic tripeptides to be transferred—across several state boundaries—to Fokrers' laboratory. Guillemin, also in a call made from the conference, asked Hoffman-La Roche to synthesize the six tripeptides which Schally would not share.

From January through the fall of 1969 there ensued a furious race to solve the structure of TRF. The finish was so close and confused that to this day both teams claim priority, although on the Schally side with some internal difference of em- phasis. Schally seems content to concede a draw, having written that the credit for solving the TRF project "had to be shared with Burgus and Gulilemin, who elucidated the structure of ovine TRH" about the same time." Fokrers, on the other hand, says flatly that "We were working totally independently of Guillemin and his team and we got it before they did."

The TRF molecule did not respond to the established chemical tests for identifying the endopeptides, so evidently nature had blocked the ends in some way.

**This is the second of three articles on the history of the pursuit of the brain's hormones by Roger Guillemin and Andrew Schally. Last week's article described how the two scientists had spent 7 fruitful years in search of the putative hormone known as CRF and a further 6 years in quest of TRF. To decide whether to continue supporting research in the field, the National Institute of Health convened a conference in Tucson, Arizona, in January 1969. Three weeks before the conference began, averting an otherwise almost certain cutoff of funds, Guillemin obtained a result of critical significance.**

*The two teams naturally have different nomenclatures for the hypothalamic hormones or factors. Schally now calls them hormones, which indeed they are, Guillemin prefers the term factor to distinguish them from the other hormones. The term CRF was first used by Saffran and Schally in 1967; the name CRF. There are different versions as to who coined the word CRF. Schally that Schally that 1st did, and Guillemin that credit belongs to R. A. Cleghorn, another member of their department. The credit for developing the word CRF is shared with some internal difference of emphasis.
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